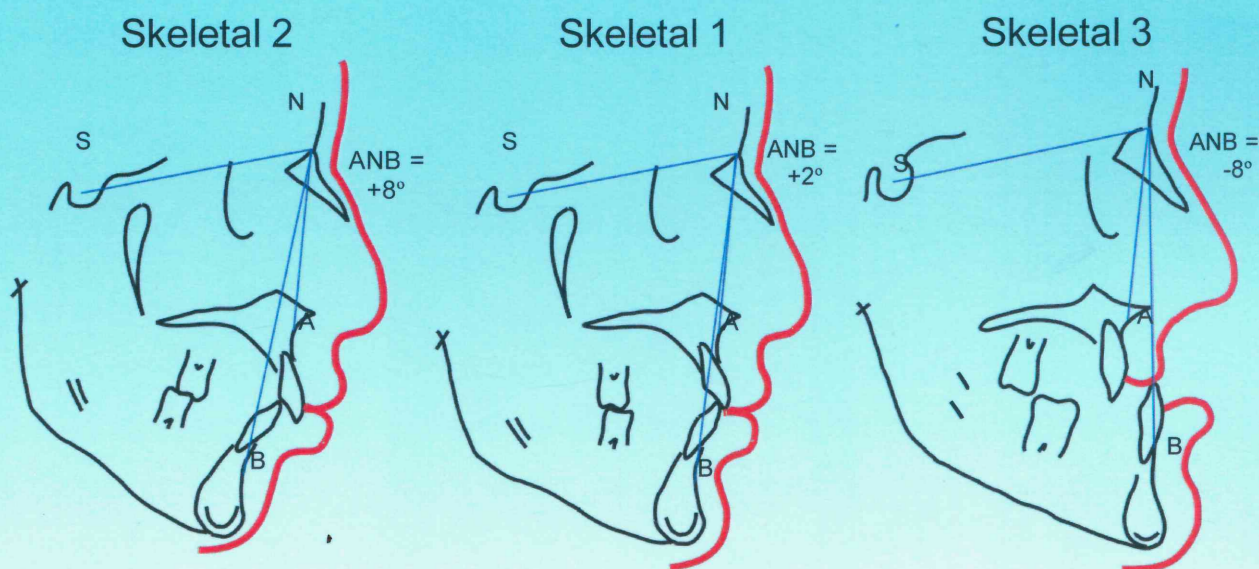


Postgraduate Notes in Orthodontics

DDS/MOrth Programme

9th Edition



Postgraduate Notes in Orthodontics DDS/MOrth Programme

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Published by the Child Dental Health Department, Bristol Dental School, University of Bristol.

1st Edition 1998	3rd Edition 2002	5th Edition 2009	7th Edition 2015	9th Edition 2021
2nd Edition 2000	4th Edition 2005	6th Edition 2012	8th Edition 2018	

ISBN: 978-0-9562712-5-9

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Preface

Again it is a pleasure to be able to introduce a new edition of the *Postgraduate Notes in Orthodontics*, this is now in its 9th Edition. I cannot believe it is over twenty years since the first edition was published. As orthodontics continues to evolve so the book continues to develop to reflect the changes in practice and assessment. This edition includes some new chapters and the 'question and answer' section has been extended to include SBA (single best answer) style questions.

Once again I would like to thank all the Bristol postgraduate students, both past and present, and staff who work hard to keep the text current and relevant. Thank you for your continued support and I hope you continue to find the book helpful.

Nikki Attack
December 2021

These notes were originally compiled during the first MSc/MOrth Programme in Orthodontics (1993-96) at the University of Bristol and subsequently revised in 2000, 2002, 2005, 2008, 2011, 2014, 2017 and 2020.

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Abbreviations

AFH	Anterior face height
AOB	Anterior open bite
AP	Anteroposterior
CL	Cleft lip
CI II/1	Class II division 1
CI II/2	Class II division 2
CI III	Class III
CLP	Cleft lip and palate
CP	Cleft palate
FA	Fixed appliance
HG	Headgear
LLS	Lower labial segment
Mand	Mandible
Max	Maxilla
MMP	Maxillary-mandibular plane
MnP	Mandibular plane
mths	Months
MxP	Maxillary plane
NiTi	Nickel titanium
OB	Overbite
OJ	Overjet
Pt	Patient
PFH	Posterior face height
R/G	Radiographs
RCT	Randomised Controlled Trial
Sk	Skeletal
SM	Study model
SS	Stainless steel
TB	Twin block
TMA	Titanium Molybdenum Alloy
TMD	Temporomandibular dysfunction
ULS	Upper labial segment
URA	Upper removable appliance
Xtn	Extraction
Yr/yr	Year/Years
→	Leads to/causes/results in
↑	Increases
↓	Decreases/reduce

Abbreviations for Journals	
Journal	Abbreviation
Acta Odontologica Scandinavica	Acta Odonto Scand
American Journal of Orthodontics	AJO
American Journal of Orthodontics and Dentofacial Orthopaedics	AJODO
Annals of the Royal College of Surgeons of England	Ann RCSEng
Angle Orthodontist	AO
Australian Dental Journal	Aust Dent J
British Dental Journal	BDJ
British Journal of Orthodontics	BJO
British Journal of Plastic Surgery	Br J Plas Surg
Cleft Palate Journal	CPJ
Cleft Palate-Craniofacial Journal	CPCJ
Dental Practice	Dent Prac
Dental Update	Dent Update
European Journal of Orthodontics	EJO
Evidence Based Dentistry	Evid Based Dent
Faculty Dental Journal	FDJ
International Orthodontics	IO
International Journal of Adult Orthodontics and Orthognathic Surgery	IJAOOS
International Journal of Paediatric Dentistry	Int J Paediatr Dent
Journal of the American Dental Association	JADA
Journal of Clinical Orthodontics	JCO
Journal of Clinical Periodontology	J Clin Perio
Journal of Dentistry	J Dent
Journal of Dental Research	J Dent Res
Journal of Maxillofacial Surgery	J Maxillofac Surg
Journal of Orthodontics	JO
Journal of Paedodontics	J Paedo
Journal of Periodontology	J Perio
Journal of Oral Surgery	J Oral Surg
Oral Surgery, Oral Medicine, Oral Pathology	Oral Surg, Oral Med, Oral Path
Orthodontic Update	Ortho Update
Orthodontics & Craniofacial Research	Ortho & Cranio Res
Progress in Orthodontics	Prog Orthod
Scandanavian Journal of Dental Research	Scand J Dent Res
Transactions of the European Orthodontic Society	TEOS

Useful Website Links

British Orthodontic Society Website	www.bos.org.uk
Cochrane Reviews (highlighted in blue in references)	www.cochrane.org/reviews
Department of Health	www.dh.gov.uk
General Dental Council	www.gdc-uk.org
Healthcare Quality Improvement Partner (HQIP)	www.hqip.org.uk
NICE	www.nice.org.uk
Royal College of Surgeons	www.rcseng.ac.uk
Scottish Intercollegiate Guidelines Network (SIGN)	www.sign.ac.uk/our-guidelines

Introduction

Orthodontics - What is it and a Brief History

Orthodontics - What is it and a Brief History

Orthodontics	The branch of dentistry which is concerned with facial growth, the development of the occlusion and dentition and with the diagnosis, interception and correction of dentofacial anomalies and craniofacial malformations	Mitchell et al., 2007
Definition	- from the Greek: - Orth(o) = straight, true, correct - Odontic = tooth, teeth	
Occlusion	arrangement and position of teeth with upper and lower teeth in contact in their usual position	
Normal occlusion	occlusion within accepted deviation of the ideal and does not constitute aesthetic or functional problems	Houston et al., 1992
Malocclusion	tooth position or jaw position outside normal range	
First description of malocclusion	- precise timing unknown - ancient Greeks were describing irregularities of the teeth as long ago as 400BC	
First description of orthodontic treatment	the Romans, notably Celsus, described the use of finger pressure to move teeth	
Earliest fixed appliance	Fauchard's Bandeau of 1726, a metallic arch tied to the labial/buccal surfaces of the teeth using fibrous ligatures	
Start of 'Modern-day' orthodontics	Developed by Edward Angle: - E-Arch (1900) - Pin & Tube (1910) - Ribbon arch (1915) - Edgewise appliance (1925) Developed by Raymond Begg: - Begg Appliance (1950) Developed by Laurence Andrews: - Preadjusted Edgewise or Straightwire™ appliance (1972)	

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Mitchell L et al., 2007, An Introduction to Orthodontics, 3rd Edition, Oxford University Press, pp. 2

Occlusion and Malocclusion

Occlusion

Development of the Occlusion

Malocclusion

Class I Malocclusions

Class II/1 Malocclusions

Class II/2 Malocclusions

Class III Malocclusions

Bimaxillary Proclination

Anterior Open Bite (AOB)

High Angle Cases

Deep Bites

Low Angle Cases

Asymmetries

Occlusion

Normal occlusion	Occlusion within accepted deviation of the ideal and does not constitute aesthetic or functional problems	Houston et al., 1992
Static occlusion	Andrews 6 Keys based on 120 non-orthodontic normals: • correct molar relationship • correct crown angulation • correct crown inclination • tight interproximal contacts • absence of rotations • flat occlusal plane Ideal molar relationship as described by Andrews • distal surface of the distal marginal ridge of 6 contacts and occludes with the mesial surface of the mesial marginal ridge of the lower 7 Bennett and McLaughlin's 7th key • correct tooth size In practice, orthodontically treated occlusions seldom achieve all occlusal keys	Andrews, 1972 Bennett & McLaughlin, 1993 Kattner & Schneider, 1993
Functional occlusion	'Ideal' functional occlusion • features not conclusively established • post-orthodontic pts did not exhibit ideal occlusal relationships Should articulators be routinely used? • although 13% of orthodontists in the USA routinely mounted pre-treatment SMs, only 6.5% mounted SMs at the end of treatment • articulation of SMs did not affect 10 orthodontists' treatment planning decisions in a meaningful manner • comprehensive approach including use of articulator, for diagnosis and treatment planning is appropriate for complex orthodontic problems Mutually protective occlusion (MPO): - immediate but gentle disclusion of all posterior teeth in lateral and protrusive contact with no associated non-working side interferences - posterior teeth protect anterior teeth in occlusion • alternative names are cuspid disclusion or canine guidance • MPO does not convey any great advantage over other functional occlusions • very few natural ideal occlusions as defined by Andrews have an MPO • majority of population (91%) have non-working side contacts in random samples • pts treated with Edgewise appliances did not show ideal functional occlusal relationships whereas most treated with Straight-Wire appliances had MPO Should ICP coincide with retruded contact position (RCP)? • general agreement that ICP should coincide with RCP, however large disagreement as to how closely they should coincide • potentially significant discrepancies: - A-P discrepancy of >1.5mm - lateral discrepancy of >0.5mm • 20% have ICP-RCP discrepancy of >2mm prior to any orthodontic treatment, yet no evidence that this is harmful	Clark & Evans, 2001 Clark & Evans, 1998 Utt et al., 1995 Ellis & Benson, 2003 Freeland, 2012 Sadowsky & BeGole, 1980; Tipton & Rinchuse, 1991 Akhoundi et al., 2009 Rinchuse, 1995 Milosevic & Samuels, 1998 Egermark et al., 2003 Utt et al., 1995

	• 40% of orthodontic pts found to have a ICP-RCP discrepancy of >2mm • orthodontics ↓ RCP/ICP interferences in some malocclusions, while it does not in others (AOB/CI III) • optimal orthodontic treatment with selective grinding in some cases, will ↓ prevalence of occlusal interferences • Roth attributes TMD and orthodontic relapse to a ICP-RCP discrepancy, however this is not substantiated • studies of post orthodontic pts have no more TMD symptoms than people with untreated malocclusions or normal occlusions • there is no link between malocclusion or functional occlusion and TMD	Hidaka et al., 2002 Olsson & Lindqvist, 2002 Roth, 1981 Sadowsky & Polson, 1984 Gesch et al., 2004
Recommended reading	Clark & Evans, 2001	

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Development of the Occlusion

Stages of dental development	3 recognised stages of dental occlusal development: • primary dentition • mixed dentition - the transitional phase • permanent dentition	
Primary dentition	• usually fully erupted by the age of 2-3yrs • features of primary dentition: - primate spaces (50% of pts) - upper arch longer and wider than lower - OJ=2mm - OB third ht of lower incisor crown - 'flush terminal plane' molars • a number of changes occur between the ages of 3-6yrs: - ↑ in intercanine width - some spacing of incisors - edge-to-edge bite - 'CI III' incisors	
Mixed dentition	• transition from primary to mixed dentition begins round about the age of 6yrs with the eruption of the first permanent molars and the lower incisors • features of the mixed dentition: - ½ unit Class II molars - physiological anterior spacing, e.g. midline diastema • occlusion accommodates the larger permanent incisors by: - permanent incisors erupting more proclined and, therefore, on a wider arc - using the primate spaces - an ↑ in lateral growth of the jaws • transition from primary to permanent dentition utilises the 'Leeway' space, approximately 1.5mm each side in max and 2-2.5mm each side in mand • lateral arch development occurs with the eruption of the canines into a wider arch position	Fleming et al., 2008 Moyers et al., 1988
Permanent dentition	• generally the permanent dentition (with the exception of third molars) is complete by the age of 14yrs • as a rule females reach full permanent dentition before males	
Why is it important to be aware of normal development?	• recognising the normal • spotting the abnormal • knowing when significant events may have happened • predicting the future? • anomalies in primary dentition, e.g. hypodontia, double teeth, linked to ↑ 60% anomalies in permanent dentition	Scott & Attack, 2015 Nik-Hussein & Abdul Majid, 1996
Recommended reading	Scott & Attack, 2015	

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Malocclusion

Definition	An appreciable deviation from normal occlusion	Houston et al., 1992
Classification (see section on Indices)	Commonly accepted classifications: Angle classification • CI I, II, III Incisor classification • CI I • CI II division 1 division 2 • CI III	Angle, 1898 British Standards Institutes, 1983
Aetiology (see diagram)	• 95% of malocclusions are due to a variation of normal development • 5% of malocclusions have identifiable cause • genetics tend to influence Sk pattern, environment influences tooth position, but both act synergistically to create malocclusion	Proffit, 1986 Lundstrom, 1984; Dibbets, 1996
Genetic influence	• Sk pattern • some syndromes, e.g. muscular dystrophy • evolutionary trend to ↓ jaw size and tooth number • molecular genetics of tooth morphology found MSX1 and MSX2 induces patterning in the incisor region, BARX1 and DLX2 induces patterning in the molar region • inactivation of APC gene or forced activation of Wnt/β signalling → supernumerary formation in humans and mice; however, key genes in pathways are not very clear	Nishio & Huynh, 2016 Mackenzie et al., 1992; Sharpe, 1995 Wang & Fan, 2011
Environmental influence	• soft tissues - teeth in a position where there is equilibrium between forces created by the lips, tongue and periodontal ligament (PDL) • habits - alter resting forces on teeth (tongue thrust/habit) • local factors - e.g. fleshy fraenum, retained primary tooth, missing teeth • pathology - e.g. cleft lip and palate, lymphangioma, odontogenic tumours • trauma - e.g. condyle fracture, postoperative scarring • respiration - minor influence on vertical and transverse jaw dimensions, ↑ effect in animals than humans; adenoidectomy in humans has been shown to cause a ↓ in lower ant face height and a slight ↑ in maxillary width; ↑ correlation between nasopharyngeal airway obstruction and Sk CI II relationships	Proffit, 1978 Bowden, 1966; Tarvade & Ramkrishna, 2015 Mars & Houston, 1990; Ross, 1987 Proffit et al., 1980 Harvold et al., 1981; O’Ryan et al., 1982; Linder-Aronson et al., 1970; El Momani et al., 2011
Recommended reading	Turner et al., 1997; Fleming et al., 2008	

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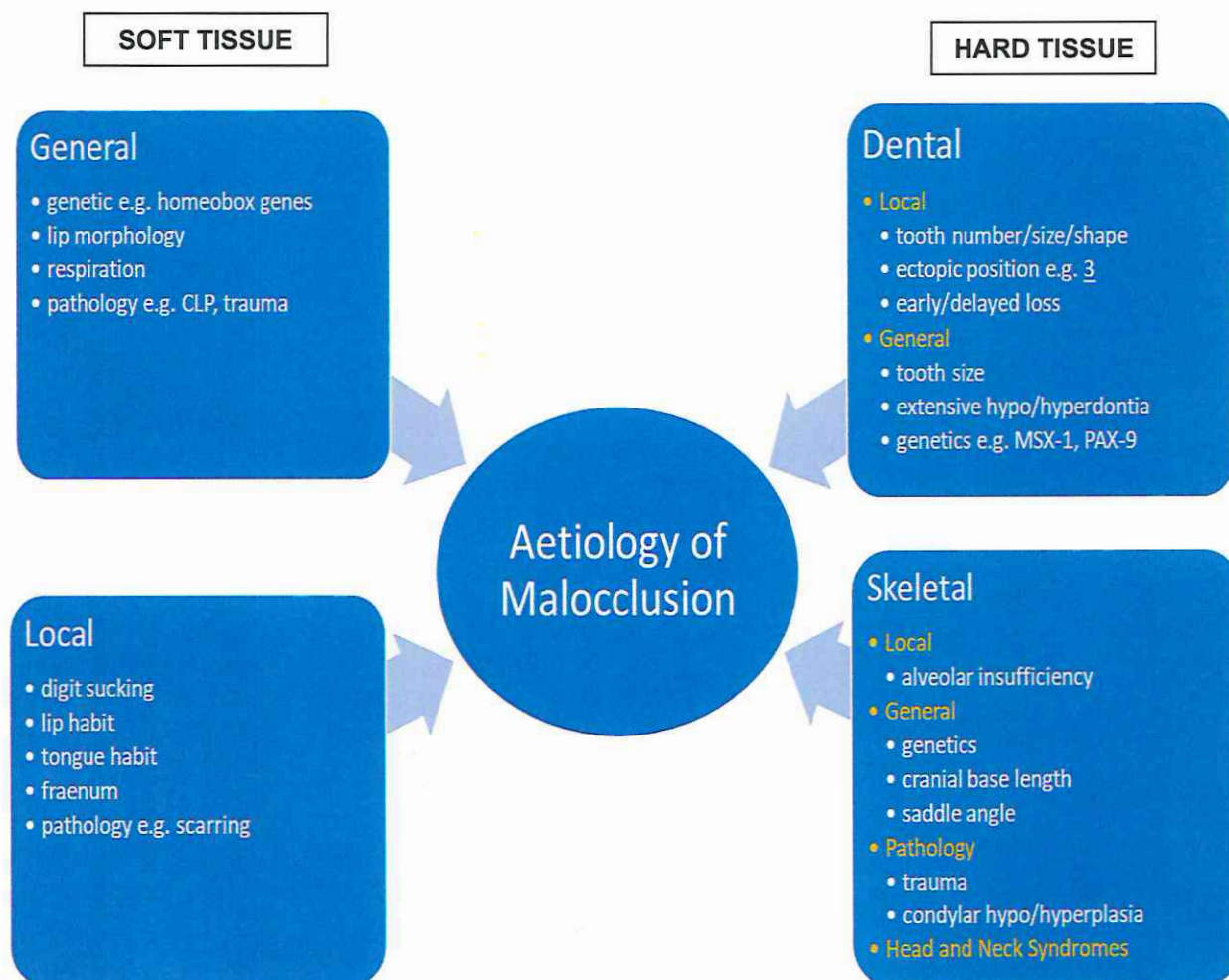
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Class I Malocclusions

Definition	By incisor relationship: the lower central incisal edges lie on or below the cingulum plateau of the palatal surface of the upper central incisors	British Standards Institution, 1983
Incidence	60%	Todd & Lader, 1988
Features	Skeletal - usually Sk CI 1, may be mild CI 2 or CI 3, with dentoalveolar compensation - vertical and transverse anomalies may be found, e.g. AOB, crossbites Soft tissues - favourable Dental - most common problem is crowding, usually due to local factors - spacing - bimaxillary proclination - vertical anomalies, e.g. AOB - transverse anomalies, e.g. crossbites, scissorsbites Facial growth - usually favourable but AOB tend to worsen as dentoalveolar compensation is already at its limits	
Treatment options	orthodontic management alone is usually required	
Crowding	managed by creation of space from Xtns or arch expansion or interdental reduction (IPR)	
Spacing	- consider whether to: - accept - composite additions (restorative only) - open/redistribute spaces and place prostheses - close space with appliances	
Bimaxillary proclination	see section on Bimaxillary Proclination	
Vertical anomalies	see sections on Low/High Angles cases, AOB and Deep Bites	
Transverse anomalies	- see section on Arch Lengthening and Lateral Expansion Crossbite - a discrepancy in buccolingual relationship of the upper and lower teeth Buccal crossbite - buccal cusps of lower teeth occlude buccal to buccal cusps of upper teeth - managed by maxillary expansion but before planning treatment consider if there is a displacement (favourable) or true asymmetry, e.g. skeletal (unfavourable), and manage appropriately - can be treated with: - URA with midline screw/coffin spring - Quadhelix - RME - AW expansion in FA - Expansion arch (attached in molar tubes) - Surgical assisted expansion Lingual crossbite (scissorsbite) - buccal cusps of lower teeth occlude lingual to lingual cusps of upper teeth - need mandibular expansion and maxillary contraction - if severe may need surgery	Gill et al., 2004 Agostino et al., 2014 McNally et al., 2005

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Class II/1 Malocclusions

Definition	By incisor relationship: - the lower central incisor edges lie palatal to the cingulum plateau of the upper central incisors - upper incisors are proclined or average inclination, $\uparrow$ OJ	British Standards Institution, 1983
Incidence	Class II/1: 20%	Todd & Lader, 1988
Aetiology	- Sk base relationships, usually CI 2 - habits, e.g. thumb-sucking - soft tissues, e.g. lower lip trapping behind upper incisors, short upper lip	Bishara, 2006
Features	Skeletal 76% have Sk 2 base, if Sk 1 incisor relationship is usually due to a habit $\uparrow$ cranial base angle $\rightarrow$ mandibular retrognathia - longer cranial base $\rightarrow$ prognathic max - may have small mand and large max - average or $\downarrow$ lower face height Soft tissues - lips may be competent or incompetent and lip pattern important in maintaining a stable result, short upper lip $\rightarrow$ OJ $\downarrow$ will be less stable - lower lip may have caused malocclusion, e.g. trapping behind upper incisors or lip-tongue seal Dental - CI II incisor relationship with proclined or average upper incisors - lower incisors may be proclined - OJ is $\uparrow$ $\downarrow$ interincisor angle - OB is usually deep and often incomplete (adaptive anterior oral seal - tongue to lower lip) - buccal segments usually CI II, may have crossbites (buccal/lingual) Mandibular position - ensure pt is not habitually posturing, treat to centric relation - consider the profile Facial growth - variable - can expect favourable growth but if pt rotates posteriorly will not help buccal segment correction (20% of pts)	Hopkins et al., 1968 Sayin & Türkkahraman, 2005 Sayin & Türkkahraman, 2005 Al-Khateeb & Al-Khateeb, 2009 Björk & Skieller, 1972
Reasons for treatment	Risk of trauma 45% $\uparrow$ risk with OJ > 9mm in 12yr olds - early treatment has small $\downarrow$ in risk but not clear if this is cost effective Improvement in aesthetics - some improvement in self concept with early OJ $\downarrow$ Reducing bullying 12.8% pts referred for treatment are bullied Relief of gingival trauma	Todd & Dodd, 1983 Batista et al., 2018; Veitz-Keenan & Liu, 2019 O'Brien et al., 2003 Seehra et al., 2011
Treatment options	- orthodontic camouflage - orthodontic decompensation and orthognathic surgery	
Aims for orthodontics alone	- dental camouflage - some mandibular growth - some restraint of maxillary growth	

	• forwards mandibular rotation • combination of above	
Favourable features for orthodontics alone	• small ANB difference • no dental compensation • growing pt • cessation of habit (if present) • compliant pt • OJ<9mm • greater component of OJ being proclination of ULS	Burden et al., 1999
Treatment aims	General - adjusted as necessary • relieve crowding • level and align the arches • ↓ OB and correct edge - centroid relationship (lower incisor edge should lie anterior to the upper root centroid) • ↓ OJ • correct the buccal segment relationships	Houston, 1989
Orthodontic treatment options	URA • simple tipping achieves desired movements - if maxillary incisors are proclined - canines mesially angulated - if lower incisors already lie anterior to upper root centroid - HG can be added to get some Sk changes Functional appliances • in growing pts • achieves normal incisor relationship • ↓ anchorage demand during FA FA/FA • if bodily tooth movement is required • if Sk pattern allows camouflage Orthognathic surgery (see section on Orthognathic Surgery) • when too severe for orthodontics alone, e.g. ANB>9° • in non-growing pts	
Timing of treatment	Treatment can be performed during: • primary dentition - NOT stable as pattern of growth re-establishes later, encourage habits to stop • mixed dentition - growth modification to be started 1-3yrs before peak adolescent growth spurt BUT transition to permanent dentition can be difficult to manage • permanent dentition - ideal treatment time is in peak/just post-peak growth period	Pavoni et al., 2018
Recommended reading	Batista et al., 2018	

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Class II/2 Malocclusions

Definition	By incisor relationship: - the lower central incisor edges lie palatal to the cingulum plateau of the upper central incisors - upper incisors (and usually lowers) are retroclined, with minimal OJ although maybe ↑	British Standards Institution, 1983
Incidence	range 10-18%	Houston et al., 1996
Aetiology	- high concordance in twin studies suggesting autosomic dominant with incomplete penetrance or polygenic model - axial inclinations of incisors is such that the lower incisor edge cannot be maintained on the upper incisor crown → deep OB, ↓ OJ 'strap-like' ↓ lip may retrocline maxillary and mandibular incisors (bimaxillary retroclination) → deep OB, ↓ OJ - high resting lip pressure against maxillary central incisors - lower lip may procline <u>2</u>	Markovic, 1992 Lapatki et al., 2002
Features	Skeletal - usually mild Sk 2 base, can be Sk 1 or Sk 3 ↑ cranial base angle → mandibular retrognathia - longer cranial base → prognathic max - max short, broad and forward relative to mand → tendency for scissorsbite in premolar region ↓ lower face height ↓ gonial angle ↓ MMP angle Soft tissues - high resting lower lip line (due to ↓ lower face height) - typically strap-like lower lip - marked labio-mental fold - high masseteric muscle forces Dental - retroclined upper and lower incisors <u>2</u>s often proclined, mesially tipped and mesiolabially rotated (lower lip fails to control shorter crown) ↑ interincisal angle - OB is usually deep - OJ is ↓ usually - extruded upper incisors - buccal segments usually CI II - scissorsbite common in premolar region due to transverse discrepancy - crown-root angle may be ↓ - incisors may be thin with a poorly defined cingulum Facial growth - variable - usually can expect favourable growth	Hopkins et al., 1968 Ingervall & Thilander, 1974; Sciote et al., 2012 Al-Khateeb & Al-Khateeb, 2009 Robertson & Hilton, 1965
Reasons for treatment	Risk of trauma - remove traumatic bite - trauma to palate, stripping of upper palatal gingiva, recession of lower labial mucosa Improvement of aesthetics - improve facial aesthetics - improve tooth alignment, in particular of the <u>2</u>s	
Treatment options	- leave and observe - orthodontics alone - orthodontic decompensation and orthognathic surgery	Millet et al., 2018

Favourable features for orthodontics only	• small ANB difference • growing pt	
Treatment aims	General - adjusted as necessary • relieve crowding • level and align the arches • ↓ OB - correct edge-centroid relationship (lower incisor edge should lie anterior to the upper root centroid) - ↓ interincisal angle, often requiring intrusion and palatal root torquing of upper incisors • correct the buccal segment relationships	Houston, 1989 Mills, 1973
Orthodontic treatment options	URA • to ↓ OB with anterior bite plane - limit incisor eruption and allow lower molars to erupt • aid correction of buccal segment with EOT • convert pt to a CI II/1 malocclusion and manage accordingly, e.g. with functional appliance • correct scissorsbite with a contraction plate Modified functional appliances • in growing pt • use cantilever springs behind the upper incisors to procline the maxillary incisors and correct the sagittal relationship with same appliances FA/FA • if bodily tooth movement is required, very likely to need torque to upper incisors • Sk problem allows dental camouflage • avoid Xtns in low MMP angle cases as space closure can be difficult • carefully consider Xtn decision, if Xtn necessary consider 5s rather than 4s to minimise lingual movement of LLS Orthognathic surgery (see section on Orthognathic Surgery) • when too severe for orthodontics alone, e.g. ANB>9° • non-growing pts	Dyer et al., 2001 Björk & Skieller, 1972
Timing of treatment	Treatment can be performed during: • mixed dentition - prevention of a deep OB can be achieved with a URA • permanent dentition	
Stability and retention	• can consider proclining the LLS, as it has been trapped • proclination of LLS after intrusion of ULS has been suggested as stable treatment as lower incisors would take up positions previously occupied by uppers, however this stability however has been questioned • consider fixed retention and pericision of rotated 2	Mills, 1968 Selwyn-Barnett, 1996 Canut & Arias, 1999 Edwards, 1970
Recommended reading	Mills 1973; Houston, 1989; Millet et al., 2018	

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Class III Malocclusions

Definition	By incisor relationship: the lower central incisal edges lie anterior to the cingulum plateau of the palatal surface of the upper central incisors	British Standards Institution, 1983
Incidence	5% - incidence of anterior crossbite 10%	Todd & Lader, 1988 Chestnut et al., 2004
Aetiology	- genetics - due to Sk pattern - pts with CLP may present with a CI III malocclusion - pathology - hormonal imbalance, e.g. acromegaly	
Features	Skeletal - usually Sk 3 base relationship ↓ cranial base angle → forwards position of mand - maxillary retrusion is the most common contributing factor, affecting 60% of all cases - sometimes a short cranial base - max short, small and narrow relative to mand which tends to be broad, therefore, crossbites likely - obtuse gonial angle - normal or ↓ MMP angle and lower face height - transverse Sk discrepancy often a feature Soft tissues - not involved in aetiology but encourage dentoalveolar compensation - lower lip may be full and pendulous Dental - CI III molar relationship, tendency to or full reverse OJ, ↓ OB, AOB may exist - incisors compensate for Sk base, i.e. proclined maxillary, retroclined mandibular incisors - max probably crowded, mand unlikely to be so - in 'pseudo' CI III there is bilateral CI I buccal occlusion and majority of teeth are in anterior crossbite Displacements - can be a displacement in order to obtain posterior occlusion due to edge-to-edge incisor contact or to unsatisfactory transverse buccal segment relationship Facial growth - tends to be unfavourable, i.e. backwards growth rotation, ↑ vertical growth	Hopkins et al., 1968 Guyer et al., 1986 Chen et al., 2008 Lin, 2007
Treatment options	- growth modification - orthodontic camouflage - orthodontic decompensation and orthognathic surgery	
Orthodontics alone aims	- dental compensation - development of A point - Sk maxillary protrusion - backwards mandibular rotation to ↓ prominence of B point - combination of above	
Favourable features for orthodontics only	- good OB - can pt reach edge to edge in centric relation? - although this is not completely reliable as it can be affected by amount of incisor compensation - low SNA - want to bring A point forwards - low lower face height - want to rotate mand downwards and backwards → ↑ lower face height - no dental compensation - low SNB or normal SNB	

	• pt past peak growth • once corrected for crowding and displacements, want molar relationship less than ½ unit CI III	
Treatment aims	General - adjusted as necessary • relieve crowding • level and align the arches • ↑ OB and OJ • correct the buccal segment relationships	
Orthodontic treatment options	URA • if 1-2 incisors are in crossbite and positive OB Anterior cross elastics • if 3-4 incisors in crossbite, minimal crowding • used in combination with disclusion with the use of GIC or composite molar build-ups 2x4 appliance • used if pseudo CI III case • mixed dentition • may be superior to URA in terms of cost effectiveness and treatment time • offers 3D tooth movement; not dependent on compliance FA/FA alone • if tooth control is needed, minimal Sk problem ANB>0° 'Orthopaedic' treatment In a review of 'orthopaedics' in CI III cases • 50% of studies showed stimulation of max growth • 90% showed inhibition of mandibular prominence • small changes seen, ? clinical relevance Protraction HG (see section on Protraction HG) • can be successful if pt shows favourable Sk features (ANB>-2°), is about 8yrs (before posterior max suture closes) in conjunction with URA in mixed dentition or FA • AP facemask treatment results not influenced by RME so should only be considered if constricted max present, however when used ↓ upper incisor proclination • early orthopaedic treatment with protraction HG is skeletally and dentally effective in the short-term • facemask treatment was skeletally effective in pts under 10yrs old (3yr follow up), although only overall change in ANB value was statistically significant; 70% of pts still presented with a positive OJ in facemask group at 3yrs • no clinically significant psychosocial benefit of early treatment • Sk change was not maintained after 6yrs but 68% of pts maintained +ve OJ • pts were also less likely to be offered orthognathic surgery if had facemask treatment (36% compared with 66% of control group) • meta-analysis of effectiveness of protraction HG concluded it was less effective on pts >10yrs; longer treatment plans if palatal expansion not used; induced greater ULS proclination • protraction HG combined with miniscrews delivers direct orthopedic forces to maxillary complex and exhibits fewer negative side effects Chin caps • → lingual tipping of LLS and clockwise rotation of mand • effective at ↓ mandibular prognathism before puberty but this is then lost with continual growth	Reynolds, 1978 Tzatzakis & Gidarakou, 2008 Hägg et al., 2004 Wiedel et al., 2015 McKeown & Sandler, 2001 Dermaut & Aelbers, 1996 McNamara, 1987 Vaughin et al., 2005 Halicioglu et al., 2014 Mandall et al., 2010 Mandall et al., 2012 Mandall et al., 2012, 2016 Mandall et al., 2016 Mandall et al., 2016 Kim et al., 1999 Halicioglu et al., 2014 Seirvu et al., 2020 Thilander, 1963 Sugawara et al., 1990; Sugawara & Mitani, 1997

	- not recommended for open bite, significant reverse OJ or compensated lower incisor cases Functional appliances - FR3 can be used, results unpredictable - FR3 might restrict mand growth but does not stimulate forward max movement - reverse TB effective in CI III early treatment but long-term stability uncertain and depends on future growth Bone Anchored Maxillary Protraction/Bollard Plates - use of miniplates to infrazygomatic crest and lower canine region with CI III intermaxillary force application to the max (girls: 11yrs, boys: 12yrs) → highly significant amount of max advancement; less mand changes were seen - light CI III elastics to miniplates - disadvantages: flaps need to be raised for insertion and removal, prominence of hooks must be precise (too prominent will traumatise mucosa, too close to bone will prevent placement of elastics)	Ko et al., 2004 Yang et al., 2014 Seehra et al., 2012 De Clerk, 2010; Hino et al., 2013
Orthodontics and orthognathic surgery options	- when too severe for orthodontic camouflage - suggested threshold for surgery: ANB>-3°, lower incisor inclination: 83°, Holdaway angle: 3.5° - DO NOT extract teeth in the lower arch in a growing pt in case surgery is required at a later date - orthodontic decompensation of the lower arch is more difficult if Xtn have been undertaken - combined surgical-orthodontic management may improve quality of life in pt with Sk CI 3	Kerr et al., 1992 Jacobs & Sinclair, 1983 Artun et al., 1990 Jiaan et al., 2019
Recommended reading	Watkinson et al., 2013; Mandall et al., 2016	

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Bimaxillary Proclination

Definition	The proclination of the upper and lower dental arches	Keating, 1986
Aetiology	dentition adapts to the Sk and soft tissue pattern	
Incidence	most common in Afro-Caribbeans and Oriental populations	
Features	Skeletal - Sk bimaxillary protrusion (prognathic jaws) ↑ ANB, due to maxillary protrusion; mild CI 2 - long, more prognathic max and mand - short posterior cranial base - smaller upper and posterior face height - divergent facial planes Soft tissues - convex facial form ↑ lip length therefore more everted - tongue thicker and longer - lips more protrusive (flaccid/full/everted), this can change the 'balance' (neutral zone) between the tongue and lips Dental - dental bimaxillary proclination - proclined LLS compensates for ANB difference - tendency for ↓ OB or AOB - larger dental arch length due to proclined teeth - steeper mandibular plane (divergent facial planes) - normal molar relationship - may have superimposed malocclusion Cephalometric - upper incisors inclination >115°, lower incisor inclination >99°, interincisal angle <125°	Keating, 1985; Carter & Slattery, 1988 Connor & Moshiri, 1985 Adesina et al., 2013 Fonesca & Klein, 1978 Carter & Slattery, 1988 Keating, 1985
Why treat?	- to improve facial aesthetics, i.e. flatten profile - to reduce ↑ OJ - to enable lip competence	Carter & Slattery, 1988
Treatment considerations	- assess each malocclusion on its own merits - premolar Xtns appropriate for crowded cases - avoid Xtns for incisor retraction alone, as relapse prone and risks reopening of spaces - do not Xtn in spaced cases - joint orthognathic approach may be needed - Xtn of four premolars can be effective in ↓ the soft tissue procumbency in bimaxillary protrusion cases 5.2 mm of 21/12 retraction to 2.4 mm of upper lip retraction - round archwire to allow tipping of teeth	Carter & Slattery, 1988 Bills et al., 2005 Bills et al., 2005
Relapse	- long-term stability is unpredictable, depends on lip pattern adapting to incisor retraction, i.e. lower lip covering more of 21/12, and becoming competent - interincisal angle during treatment relapsed by 20% in a treated Caucasian sample ↑ relapse rate as teeth occupy a position of balance between pressure of tongue on one side and lips/cheeks on the other so if moved may shift equilibrium	Keating, 1986
Recommended reading	Keating, 1985, 1986	

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Anterior Open Bite (AOB)

Definition	Condition where there is no contact and no vertical overlap of the lower incisor crowns by the upper incisor crowns when mand is in full occlusion	Houston et al., 1996
Incidence	• 2-4% of children • 4% of adults • more common in Africans (5%) and Afro-Caribbeans	O'Brien, 1993 Todd & Whitworth, 1972 Noar & Portney, 1991
Aetiology	Genetic Environmental • habits (if prolonged into mixed and permanent dentition) • abnormal tongue function (endogenous or adaptive tongue thrust) • trauma/pathology affecting condyle • pathological, e.g. CLP, acromegaly, trauma • neurological disturbances • muscular dystrophy • iatrogenic, e.g. extrusion of molars during treatment • respiration - minor influence on vertical and transverse jaw dimensions, ↑ effect in animals than humans	Fletcher, 1975 Linder-Aronson, 1972; Harvold et al., 1981
Classification	• classification based on the appearance of the mand - dentoalveolar: mand appears normal - Sk: mand appears abnormal	Kim, 1974
Features	↑ variability in dental and Sk morphology in pts with open bites Skeletal AOB <i>Extra oral features:</i> • long face • lip incompetence • steep FMP angle • marked antegonial notch • ↑ AFH, ↓ PFH with reduced UFH:LFH • long max, short mand <i>Intra oral features:</i> • mild crowding with upright incisors • may occlude only on 7s if severe • gingival hypertrophy due to mouth breathing • maxillary, occlusal and palatal planes tilt upwards, mandibular occlusal plane canted downwards Dental AOB (most commonly due to digit-sucking habit) <i>Extra oral features:</i> • no unusual features <i>Intra oral features:</i> • arches will have features related to the AOB aetiology, e.g. thumb-sucking may procline upper incisors, depress and retrocline mandibular incisors • open bite limited to incisor region, often asymmetrical • maxillary arch may be narrow, presence of crossbites • tilting of max plane and ant displacement • 'Fish mouth' appearance • severity depends on: age, intensity, frequency, duration (↑6hrs) • CI II tendency Swallow/Abnormal tongue function • have tongue-thrust type swallow to form lip seal	Cangialosi, 1984

Cephalometric features of skeletal open bite	- maxillary palatal plane normal, occlusal plane canted - may have ↓ dentoalveolar height anteriorly, may be excessive posteriorly - Jarabak ratio: ≤ 58 high angle case	Dung & Smith, 1988
Treatment options	- stop any habits - orthodontic approach - orthognathic approach - combination of treatment 'The greater the skeletal elements contribute to the aetiology, the poorer the prognosis for treatment'	Mizrahi, 1978
Treatment of Skeletal Open Bite	- incisors are already maximally erupted, therefore cannot extrude further - do not distalise molars, Xtn distally as this allows reduction in MMP - combined orthodontic/surgical approach - TADs to intrude the buccal segments	Mizrahi, 1978; Aras, 2002 Park et al., 2004
Treatment of Dental Open Bite	- stop habit if present - change in tongue posture with tongue crib/spurs, some success has been described - no treatment for endogenous tongue thrusts - active orthodontic treatment should aim to prevent extrusion of molars and restrict vertical development of the post max, therefore avoid intermaxillary elastics - removable and fixed palatal cribs can ↓ AOBs; quadhelix with crib appliance successfully ↓ AOB with significant downward rotation of palatal plane - intrusive HG - high pull HG + transpalatal arch mainly for CI II pts to intrude 6s and prevent palatal cusps dropping - buccal intrusion split and high-pull HG - FA and vertical anterior elastics - curve of Spee in lower arch - magnets in bite blocks not much help, difficult to distinguish between the effects of the bite blocks and the magnets, may cause crossbites to develop <i>Kim mechanics</i>: use multiloop wires/rocking chair NiTi with ↑ curve of Spee in max, reverse in mand to tip molar teeth backwards and vertical elastics to close the bite - change was mainly dentoalveolar, similar to natural dentoalveolar compensation - retrospective study (small sample: 32) compared Begg, Edgewise and Andresen appliances, some with chin caps - found that FA groups had mand rotation downwards and backwards whilst functional appliance group rotated forwards and upwards BUT difficult to analyse the results as unusual cephalometric assessment used - in CI II/1 cases with proclined incisors, retraction of incisors ↑ OB - use of TADs: can be used to intrude buccal teeth which may help to ↑ OB - different treatment modalities have been investigated however due to limitations in the studies the results should be interpreted with caution - other modalities have been suggested including: -corticotomy assisted molar intrusion -post build-ups in conjunction with FA	Borrie et al., 2015 Huang et al., 1990 ; Taslan et al., 2010 Mucedero et al., 2013; Salviero et al., 2017 Firouz et al., 1992 Kalra et al., 1989 Kim, 1987; Kucukkeles et al., 1999 Chang & Moon, 1999 Arat & Iseri, 1992 Sarver & Weissman, 1995 Kravitz et al., 2007; Cousley, 2014 Lentini-Oliveira et al., 2014 Akay et al., 2009; Vela-Hernández et al., 2017
Stability	<0.5mm relapse over 2yrs post Kim mechanics (OB ↑ by 4mm during treatment) - most accurate predictor is the amount of OB at start of treatment	Kim et al., 2000 Kim, 1974

	• surgical and nonsurgical correction stability of AOB is >75%, but interpreting results with caution as variability between studies • correlation between FMP and OB unreliable • surgical correction reported to have 43% relapse rate • no single parameter gives prediction of stability	Greenlee et al., 2011 Denison et al., 1989 Lopez-Gavito et al., 1985
Relapse	Attributed to: • unfavourable growth • soft tissue factors (unfavourable tongue posture) • resumption of digit habit • inappropriate orthodontic tooth movement, e.g. incisor extrusion • surgery that has ↑ PFH (e.g. mand procedure only to close AOB) • ↑ stability of AOB correction with orthognathic surgery, no difference between Xtn, non-Xtn or type of malocclusion • AOB correction with molar intrusion using Sk anchorage is as unstable as surgical treatment (10-30% relapse rate)	Burford & Noar, 2003 Al-Thomali et al., 2017 Espinosa et al., 2020
Other useful papers	Predictors of problem cases • no cephalometric predictors exist, 300 pts examined; OB depth indicator (ODI) and extent of AOB at start of treatment were the best predictors of success	Dung & Smith, 1988
Recommended reading	Dung & Smith, 1988; Burford & Noar, 2003; Greenlee et al., 2011; Lentini-Oliveira et al., 2014	

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High Angle Cases

Definition	- Frankfort mandibular planes angle (FMPA), the angle made by the Frankfort horizontal (orbitale-porion) and the mandibular plane (Go-Me), is ↑ - normal = $27 \pm 5^\circ$, → high angle is > 1 SD above normal	Dung & Smith, 1988
Aetiology	↑ anterior lower face height (ALFH) or ↓ posterior face height (PFH) which result in a backwards growth rotation	Houston, 1988
Relevance of ↑ FMPA to orthodontics	May have the following: - dentoalveolar compensation (i.e. retroclined LLS) - crowding - reduced/incomplete OB or AOB - marked ANB discrepancy ↓ muscular forces - gummy smile/VME (vertical max excess) - bite opening ↑ OJ	Betzenberger et al., 1999 Proffit et al., 1983
Treatment principles	Related to features above: - do not procline LLS to normal values - do not aggravate growth rotation, i.e. avoid CI II traction and bite opening functional appliances - maintain OB if ↓, e.g. sectional arches to pick up high canines - avoid CI II traction which may extrude lower molars - use transpalatal arch with high pull HG to avoid upper molar palatal cusps dropping down - Xtn more distally in arch ↓ MMPA during treatment - space closure does not occur quicker in high angle cases than in low angle cases - caution with bonding 7's	Houston, 1988 Aras, 2002 Ireland et al., 2016
Treatment of AOB	see section on AOB	
Predictors	Anatomical predictors - Björk's 7 structural signs help to predict type of growth rotation (see section on Growth Rotations) - others have investigated these further and found that only in severe cases were they found to be of use - pre-treatment lat cephs cannot predict future growth rotations Cephalometric predictors - many have been used: - SN-MP angle > 40° - OB Depth Indicator (ODI) - Occlusal/MnP angle > 22° - UFH / LFH ratio < 0.7 - PFH / AFH (Jarabak) ratio < 58% - OB - MMP angle > 32° - only degree of OB present at start of treatment and ODI found to show any relationship to difficulty in treatment 191 subjects with SN / MnP > 40°: 50% had normal OB, 30% had deep OB and 20% had AOB	Björk, 1969 Skieller et al., 1984 Leslie et al., 1998 Dung & Smith, 1988 Kim, 1974 Betzanberger et al., 1999
Miscellaneous	- Jarabak ratio = PFH:AFH, 59 - 63 is normal; if $\geq 64 \Rightarrow$ low angle case, deep OB; $\leq 58 \Rightarrow$ high angle case, ↓ OB - Sassouni analysis useful for assessing facial heights	Jarabak & Fizzell, 1972 Sassouni, 1969

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Definition	• ↑ vertical overlap, beyond average (2-4mm), of the upper incisors with the lower incisors • complete to tooth/soft tissue or incomplete	
Aetiology	Skeletal • anterior growth rotation due to ↓ anterior lower face height (ALFH) or ↑ posterior face height (PFH) Soft tissue • high lower lip line (due to ↓ anterior lower face height) • ↑ mentalis muscle activity (strap-like) • ↑ masseteric forces Dental • excessive eruption of incisors esp. lower incisors • resting tongue position and swallow will determine whether OB is complete or incomplete • retroclination of incisors	Björk & Skieller, 1972 Ingervall & Thilander 1974; Sonnesen & Bakke, 2005
Indications for treatment	Primary dentition • deep OB may occur in 1° dentition, however treatment is likely to relapse if treated early therefore rarely indicated Early permanent dentition • trauma to soft tissues palatal to max incisors or labial to mand incisors • traumatic OBs associated with poor OH (IOTN 4f)	Naini et al., 2006
Planning considerations	• Age - extrusion in adults unstable • Soft tissues - smile line, should show 2-4mm at rest • A-P skeletal - growth modification or surgery • Vertical skeletal - short face - extrusion of buccal segments - long face - avoid extrusion of buccal segments	
Aims	• relative intrusion of incisors • absolute intrusion of incisors • proclination of LLS • extrusion of molars	Eberhart et al., 1990
Methods of OB reduction	No one treatment method is superior URA • URA with anterior bite plane in growing pts to accommodate ↑ in vertical dimension ± ↓ FA • Dahl appliance • functional appliance: MOA allows eruption of lower posterior teeth FAs • bond incisor brackets more incisally • SS full thickness archwires - to level bracket slots; tip in canine brackets, especially distoangular 3, will cause incisor extrusion in light aligning wires; as canines upright, incisors will reintrude: vertical 'round tripping' • incorporate 7s giving ↑ vertical post anchorage • upper ↑ curve of Spee (COS) and lower reverse COS, can consider using 'counterforce' NiTi AW (these can distort archform with prolonged use) • Tip-Edge - anchor bends, intrude labial segments • lingual appliance, e.g. Incognito, WIN Segmental archwires - i.e. Ricketts' utility arch & Burstone's intrusion arch (segmental mechanics)	Millett et al., 2018

	Auxillaries • bite turbos • microscrews, can be used to intrude labial segments • low pull HG • CI II elastics • fixed intermaxillary traction, e.g. Advansync • use of TADs Orthognathic surgery • 3 point landing followed by premolar extrusion • segmental surgery, e.g. Kole procedure	Senişik & Türkkahraman, 2012
Stability	The following have been suggested: • good inter-incisal angle - occlusal stop • edge-centroid relation - no evidence this is more stable • long-term retention	Mills, 1973 Houston, 1989 Mills, 1968
Recommended reading	Millet et al., 2018	

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Low Angle Cases

Definition	- Frankfort mandibular planes angle (FMPA), the angle made by the Frankfort horizontal (orbitale-orion) and the mandibular plane (Go-Me), is ↓ - normal = $27 \pm 5^\circ$, → low angle is >1 SD below normal	
Aetiology	↓ anterior lower face height (ALFH) or ↑ posterior face height (PFH) which result in a forwards growth rotation - anterior growth rotation (counterclockwise) most common (average -7°)	Björk & Skieller, 1972
Relevance of ↓ FMPA to orthodontics	May have the following features: - proclined LLS ↑/complete OB ± palatal trauma - square face with hypertrophic masseters ↑ muscular forces	Hunt et al., 2006 Ingervall & Thilander 1974; Sonnesen & Bakke, 2005
Treatment principles	Related to features above: - avoid mandibular Xtns as space closure may be difficult, however space closure during FA treatment is affected more by gender and active growth than FMPA - can procline LLS beyond normal values (ideal angle for LLS is 120° - MMPA) - ways to ↓ OB: ↓ OB if increased, e.g. URA with anterior bite plane in growing pts ± ↓ FA - functional appliance, e.g. MOA allows eruption of lower posterior teeth; trim upper TB and do not crib lower 6's - FAs - upper ↑ curve of Spee (COS) and lower reverse COS, segmental archwires, i.e. Ricketts & Burstone, bite turbos, microscrews, low pull HG, Class II elastics, lingual appliances - banding 7s possibly extrudes 6s and 5s - in adults no residual growth remaining therefore ↓ OB via incisor intrusion or proclination 5° proclination reduces overbite by 1mm - surgery to ↓ OB - i.e. 3 point landing followed by premolar extrusion or Kole segmental surgery - Tip-Edge anchor bends - lingual appliance - acts as bite opening appliance	Ireland et al., 2016 Millett et al., 2018 Naini et al., 2006 Clifford et al., 1999 Eberhart et al., 1990
Predictors	Björk's 7 structural signs reports to help predict type of growth rotation (see section on Growth Rotations)	Björk, 1969
Miscellaneous	- Jarabak ratio = PFH:AFH, 59 - 63 is normal; if $\geq 64 \Rightarrow$ low angle case, deep OB; $\leq 58 \Rightarrow$ high angle case, ↓ OB - Sassouni analysis useful for assessing face heights	Jarabak & Fizzell, 1972 Sassouni, 1969

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Asymmetries

Definition	Dissimilarity of parts on either side of a straight line or plane, or about a centre or axis; clinically: imbalance or disproportionality between left and right side of face	Chia et al., 2008
Incidence	• common, no significant gender differences • most people have asymmetry in the face and dentition, this is usually mild • lay people only notice centreline discrepancy >2mm • ↑ perception of facial asymmetry in dental professionals than lay people	Meinik, 1992 Johnston et al., 1999 Al Hammadi, 2019
Aetiology	Developmental (1st and 2nd arch structures) • hemimandibular elongation/hyperplasia • hemifacial microsomia/hypertrophy/atrophy (Parry-Romberg syndrome) • achondroplasia • torticollis • unilateral CLP Environmental • intra-uterine pressure • condylar hyper/hypoplasia • excessive condylar growth • habits Pathological • tumours and cysts, e.g. osteochondroma • infection • condylar resorption Trauma • condylar fractures ± ankylosis Functional • mandibular deviations, e.g. premature contacts Local factors e.g. retained/missing teeth	Bishara et al., 1994; Chia et al., 2008 Proffit et al., 1980
Classification	Skeletal • maxillary, mandibular or combination with muscular Muscular • masseteric hypertrophy • craniofacial atrophy • cerebral palsy Functional • mandibular displacement due to constricted max → premature contact • TMJ dysfunction Dental • retained/missing teeth • traumatic loss of permanent teeth • size of teeth • ectopic eruption • habits, e.g. thumb-sucking	Bishara et al., 1994
Clinical examination	Skeletal • vertical - assess cant of maxillary plane relative to interpupillary plane • transverse - look from top of pt's head for deviation of chin point in relation to facial midline • AP: CI 3 Sk pattern: sign of hemimandibular hypertrophy; CI 2 Sk pattern: sign of hemimandibular atrophy Soft tissue • transverse - assess bilateral symmetry and for deviation of the dorsum and tip of the nose and the philtrum	

	Dental - check for displacement on closure and examine in both centric occlusion and relation: • vertical - assess open bites • transverse - examine crossbites, buccolingual tooth position, relationship of the dental midlines with respect to each other and to the facial midline • AP - assess buccal segment relationships • localized factors - missing teeth etc • check lower centreline in relation to chin point; if coincident then likely to be skeletal in origin	
Supplementary records	R/Gs • lateral cephalogram little value for symmetry evaluation • DPT shows condyles, bony and dental structures of jaws • PA skull good for assessing right and left Photographs Laser scanning/stereophotogrammetry • acquiring 3D images using multiple photographs of same object at different angles • can quantify facial morphology and detect changes in growth and development of face • non-invasive and reproducible → enable monitoring of facial asymmetry as image comparison possible through software • allows comprehensive analysis Study models (SM) • demonstrate arch asymmetries Face bow record • with SMs demonstrates relationship of jaws in all 3 planes Technetium isotope scan • R/Gic procedure with short-lived gamma-emitting isotope which shows 'hot' spots of active growth • useful to assess condylar activity • false negatives common, so interpret results with caution • dose equivalent = 20 chest X-rays CT/Cone Beam CT/MRI • MRI can demonstrate soft tissue asymmetry • 3D CT reconstruction can be very useful	Alqattan et al., 2015 Sievers et al., 2012
Management	• management is challenging, depends on the aetiology therefore careful assessment and diagnosis is vital • diagnose aetiology of asymmetry, aim to minimise maxillary cant during growth, especially in craniofacial microsomia Skeletal • mild Sk asymmetries may be managed by orthodontics alone, e.g. hybrid functional appliances in growing pts, although pt must be aware of compromise • severe Sk asymmetries difficult to treat, treatment timing depends whether growth is excess or deficient; require joint orthognathic approach or distraction osteogenesis • >4mm mand asymmetry may be noticed Soft tissue • augmentation/reduction surgery involving bone grafts and implants may be needed Functional • habitual displacements may need an occlusal splint for diagnosis and deprogramming • severe deviations will need orthodontic treatment, often involving maxillary expansion • occlusal adjustments may correct minor deviations	Bishara et al., 1994 McAvincney et al., 2014

	Dental • missing teeth can be managed with appropriate Xtn patterns or restorative approach • asymmetric buccal segment relationships can be managed with asymmetric Xtn patterns and asymmetric mechanics • asymmetric transverse relationships may need asymmetric torque	
Recommended reading	Bishara et al., 1994; Chia et al., 2008	

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Growth

Embryology

Growth Control and Growth Centres

Growth Rotations

Growth and its Relevance to Orthodontics

Bone Metabolism

Tooth Movement

Tooth Anatomy

Chronology of Tooth Development

Embryology

3 stages of development	Ovum • 0-8 days in utero (IU) • fertilised ovum → rapid mitosis → morula → blastocyst → implantation Embryonic period • from 2nd to 12th week IU • subdivided into: <u>presomite period</u> from 8-20 days IU 1° germ layers formed: <i>Endoderm</i> - forms gastro-intestinal systems <i>Ectoderm</i> - forms cutaneous and neural systems, infolding of ectoderm forms → <i>Mesoderm</i> - forms cardiovascular system, bone, muscle, connective tissue and ectomesenchyme which originates from edges of neural tube (neural crest cells), migrates throughout head and neck region <u>somite period</u> from 21-31 days IU, basic patterns of main body systems/organs formed <u>postsomite period</u> from 4-10 weeks IU, rapid organ growth, development of external features, head growth dominates Fetal period • from 3-9mths • head development exceeds rest of body • reportioning of body components occurs • organogenesis/tissue differentiation not features	
Role of cranial neural crest cells (CNCC) in the head	• CNCC are a multipotent cell population that is largely responsible for forming the vertebrate head • CNCC are capable of differentiating into various somatic cell types, including melanocytes, craniofacial cartilage and bone, smooth muscle and peripheral nervous cells • CNCC from: 1. anterior neural fold forms much of epidermis of forehead and frontonasal regions, epithelium of 1° palate and nasal cavities 2. posterior neural fold forms epidermis of maxillary and mandibular regions, 2° palate and dorsum of tongue • CNCC migration discovered via: 1. ³H labelled thymidine CNCC 2. cell mapping in chimaeric embryos • pre-migration neural crest cells (NCC) are pluri-potential • specific differentiation regulated by environmental factors • interaction with maxillary/mandibular ectoderm necessary for chondrogenesis/osteogenesis • NCC invade pharyngeal arches → ectomesenchyme (week 4)	Noisa & Ravio, 2014 Thorogood & Ferretti, 1992
Patterning	• regulatory genes known as homeobox genes exist • homeobox genes are a large family of genes first described in <i>Drosophila Melanogaster</i> (fruitfly) • all homeobox genes contain specific highly conserved region of 180 nucleotide base pairs • homeobox genes encode a 60-amino acid sequence (homeodomain) which binds to DNA mediating <u>transcription</u> • Hox genes best studied homeobox genes but few are expressed in the head, restricted to posterior cranial region, abnormal ectopic expression in anterior structures → craniofacial dysmorphologies	Holland, 1988 Whiting, 1997

	• Non-Hox homeobox genes expressed in abundance in craniofacial region • product of these genes bind to downstream genes and regulate expression • specific genes for each axial level of embryo and are transmitted to corresponding brachial arch via NCC • no Hox gene expression in max and mand, Dix genes responsible for patterning of jaws	
Landmark dates	Facial development • begins 4th week IU Ossification of calvarium • begins 8th week IU • intramembraneous ossification • 8 centres Ossification of cranial base • begins 3rd mth IU • endochondral ossification Ossification of max • begins 7th week IU • intramembraneous ossification • 2 centres Ossification of mand • begins 6th week IU • intramembraneous ossification • 2 centres by bifurcation of inferior dental nerve 1° palate/lip fusion • 6th week IU • classically thought to be 'fusion' of frontonasal and maxillary processes • now thought to be due to 'fusion' of maxillary processes with frontonasal process submerged beneath these 2° palate • vertical shelf development from maxillary processes initially 6th week IU • shelf elevation 7-8th week IU • fusion occurs initially posteriorly to 1° palate then continues posteriorly, finally to nasal septum • complex interaction for elevation: - ↑ synthesis of EGF and TGFβ - internal shelf forces i. proteoglycan content of extracellular fluid ii. Type I collagen ? contraction iii. differential cell proliferation iv. ↑ vascularity - tongue movement	Ferguson, 1988; 1995
Teratogens	• Vit. A/retinoids induces ectopic Hox and homeobox gene expression • alcohol ↑ programmed cell death and suppresses prechordal plate outgrowth, thereby ↓ neuroectoderm and neural crest induction and causing holoprosencephaly • ionising radiation damages DNA and ↑ programmed cell death • methotrexate and anti-convulsive drugs interfere with folate metabolism → birth defects including oral clefts • others hypoxia, hyperthermia	Whiting, 1997 Smith et al., 2014 Hartridge et al., 1999

Basis of craniofacial malformations	Theories • deficiency in number/migration of CNCC • ↓ cell division resulting in fewer cells • ↑ cell adhesion, number of CNCC normal but fewer reach areas of face • defect in interaction between CNCC and epithelium	
Recommended reading	Moore et al., 1993; Meikle, 2002; Cobourne 2004, 2007	

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Growth Control and Growth Centres

Definition of growth centre	- location at which independent (genetically controlled) growth occurs, e.g. synchondroses (not to be confused with centres of ossification which occur in each bone, e.g. at the cranial sutures) - growth centres are also growth sites	
Definition of growth site	- location at which growth occurs - growth sites are not always growth centres, e.g. cranial sutures - growth occurs in response to stimulus	
Definition of growth	an ↑ in size and number - development implies an ↑ in specialisation of function	Houston et al., 1993
What initiates growth?	principally somatotrophin hormone (growth hormone) released from the pituitary gland	
What controls the extent and timing of growth?	Genetic control - highly conserved homeobox genes provide the genetic "blue print" for growth and development - these genes are the same in all animals and are highly conserved - gives rise to family resemblances - a disturbance of these genes can cause chromosome defects such as Trisomy 21 (Down's syndrome) Environmental factors - psychological stress in emotionally deprived children inhibits the release of growth hormone although the precise mechanism is unknown - Moss's functional matrix theory 'growth of the face occurs as a response to functional needs and is mediated by the soft tissue in which the jaws are embedded', e.g. the orbit grows as a result of eye growth, brain growth causes ↑ in cranium size	Moss & Salentijn, 1969
Theories of craniofacial growth	- Sutural theory (Sicher) - Cartilaginous theory (Scott) - Functional matrix theory (Moss) - capsular and periosteal matrices	
Evidence for each component	Sutural theory - old school of thought: the sutures had innate growth potential and that the sutures pushed apart the bones → an ↑ in size - this was disproved by transplanting a suture, no sutural growth was produced - however when a suture is stretched → growth showing that there is some external environmental force - sutures do not grow actively, they respond with passive deposition of bone between stretched edges of sutures Cartilaginous theory - suggests the 1° determinant of growth is the cartilage - transplanting a nasal septum cartilage into other tissues produces some growth of the septum indicating some innate growth potential exists - removing the nasal septum from rabbits produces a retrusive midface - however this could be due to the traumatic surgery - transplanting a condyle produces no condylar growth - in 75% of cases no impairment in growth is seen following a condylar fracture in growing children - transplanting the spheno-occipital synchondrosis into tissues does produce growth of this cartilage	Ryoppy, 1965 Copray, 1986 Sarnat, 1976 Rønning & Koski, 1969 Profitt et al., 1980 Copray & Duterloo, 1986

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Growth Rotations

Definitions	- mand growth rotations are a reflection of differential growth in the AFH and PFH - growth rotations usually refer to the mand - max also shown to rotate during growth	Houston, 1988
Terminology	True rotation of the mand - the rotation of the mandibular body relative to the anterior cranial base as registered by implants or stable trabecular structures in the mand - it is the fundamental rotation between the mand and cranial base Angular remodelling of lower border (intramatrix rotation) - the angular change of the mandibular line when the mand is registered on implants or stable mandibular structures Apparent mandibular rotation (matrix rotation) - the angular change in the orientation of the mand's lower border relative to the cranial base and is the result of true mandibular rotation and lower border remodelling which masks 50% of the true rotation of the mand - rotation apparent from conventional lateral cephalometric R/G	Solow & Houston, 1988 Solow & Houston, 1988 Solow & Houston, 1988 Björk & Skieller, 1972
History	- technique to study bone remodelling carried out in 1955 involved placing tantalum alloy rods into areas of facial bones thought to be stable - found the angular relationship of the line of mandibular implants changed in relation to the cranial base - found that the ramus undergoes little change in its inclination with the cranial base and that rotation occurs principally by remodelling at the lower border	Björk, 1955
Mandibular remodelling	- on average, apparent rotation is approximately 50% of true rotation of the lower border 50% of true rotation masked by remodelling - at posterior border apparent rotation is 20%, → a more efficient 'counter remodelling' process	Solow & Houston, 1988
Direction of rotation	80% of people are 'forwards' or anterior rotators, i.e. with the pt facing right the jaws rotate anti-clockwise and are assigned with a negative sign 20% of people are 'backwards' or posterior rotators	Björk & Skieller, 1972
Degree of rotation	-15° of 'true rotation' rotation occurs on average from age 4yrs to adulthood which is favourable in Sk CI 2 cases as 'B' point will tend to move forwards as the jaws rotate - on average - mand rotates $-7^{\circ} \pm 22^{\circ}$ - max rotates $-2.8^{\circ} \pm 7^{\circ}$	Björk & Skieller, 1972
Centre of rotation	- forwards (anterior) rotation at: i) condylar head ii) lower premolars iii) lower incisal edges - backwards (posterior) rotation at: i) condylar head ii) distal occluding molars	Björk & Skieller, 1972 Björk & Skieller, 1972
Clinical relevance of growth rotations		
Posterior rotation	- pts develop ↑ anterior vertical face height and 'long face appearance', possibly with a high MMP angle - pts → more Sk CI 2 with rotation as 'B' point moves backwards - pts may develop ↑ lower incisor crowding - difficult to maintain +ve OB as OB ↓ with growth - may progress to a Sk AOB and progressively retrusive chin - excessive posterior rotation and increased lower AFH ↑ need for Xtns for arch levelling	Björk & Skieller, 1972 Björk & Skieller, 1972

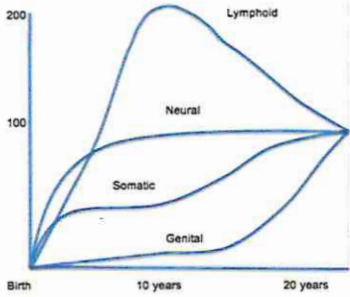
Anterior rotation	- OB deepens with growth rotation and is difficult to ↓; a developing deep OB and CI II/2 incisal relationship may need a bite plane to prevent the OB ↑ - may mask any slight maxillary AP growth inhibition achieved with HG - may develop ↑ lower incisor crowding - deep OB and forwards growth rotation may mean slower space closure	Björk & Skieller, 1972 Mills, 1978 Björk & Skieller, 1972
Effects of treatment	- intermaxillary elastics, anchorage bends and anterior bite planes can produce a temporary posterior rotation - space closure is more favourable in growing pts as about 50% of the closure is due to jaw rotation	Houston, 1988 Stephens & Houston, 1985
Prediction of direction of growth rotation	- using cases with severe Sk discrepancies, researchers used multivariate analysis to identify the variables which most strongly predicted the correct direction of growth - used 'natural reference structures' for superimposing their lateral cephalograms, i.e. menton, inner cortical structure of the inferior border of mandibular canal, and lower contour of the molar tooth germ (prior to root formation) 7 variables (structural method) which most strongly predicted the correct direction of growth were: i. intermolar and interpremolar angle ii. interincisal angle iii. lower AFH iv. lower mandibular border shape (antegonial notch indicating a posterior growth rotator) v. inclination of mental symphysis vi. inclination of condylar head vii. curvature of the mandibular canal - the ↑ the number of variables present then the stronger the likelihood of a correct prediction - studies have cast doubt on predictive ability of these values in the majority of the population	Skieller et al., 1984 Björk, 1969 Björk, 1969 Leslie et al., 1998; Kolodziej et al., 2002
Note	- Björk's work was undertaken on a few pts who happen to be severe Sk discrepancy cases so results should be interpreted with this in mind - the ability of 5 experienced clinicians to differentiate extreme backward rotators from forward rotators using cephalograms has been tested and results found to be no better than chance	 Baumrind et al., 1984
Recommended reading	Björk, 1969; Solow & Houston, 1988	

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Growth and its Relevance to Orthodontics

Definition of growth	an ↑ in size and number - in the context of orthodontics this includes an ↑ in specialisation	
Definition of growth site	location at which growth occurs	
Definition of growth centre	location at which independent, or genetically controlled, growth occurs	Mills, 1983
Cranial vault	- intramembranous ossification - ossification occurs during the 8th week IU from 8 growth centres - growth occurs by apposition at sutures and remodelling due to 'functional matrix' of expanding brain	
Cranial base	- endochondral ossification - cartilaginous synchondroses act as primary growth centres: the fronto-ethmoidal, spheno-ethmoidal, spheno-occipital and baso-occipital synchondroses - growth at the spheno-occipital and spheno-ethmoidal affect the AP and vertical relationships of the jaws	
Naso-maxillary complex	- intramembranous ossification except for nasal cartilage - ossification occurs around the 7th week IU - it is the 3rd bone to ossify after clavicle and mandible - main ossification centres appear bilaterally above the future primary canine close to where the infra-orbital nerve gives off the anterior superior alveolar nerve - growth occurs by apposition at sutures and surface remodelling with alveolar development to allow eruption of teeth - growth is directed by orientation of the sutures forwards and downwards; orbits translated upwards and laterally	
Mandible	- intramembranous ossification - ossification occurs around the 6th week IU - the 2nd bone to ossify after the clavicle - ossifies laterally to Meckel's cartilage - ossification centres appear bilaterally at the bifurcation of the ID nerve into the mental and incisive branches - growth occurs by apposition at sutures and remodelling due to the 'functional matrices' of attached muscles (respiration, eating, head posture) - as the mandible is displaced forwards, growth at the condylar cartilage fills in posteriorly - initially separate, it becomes incorporated and grows up, back and out at 45° - bone is deposited on the posterior border of the ramus and resorbed on the anterior margin - leads to an ↑ in length of the mandible ↑ in ramal height by condylar growth ↑ in body height due to alveolar development to allow eruption of teeth 2/3 of jaw growth is complete at age 10yrs	Behrents, 1985
Overall facial growth, growth patterns and post natal growth	- head occupies 30% of the body length at birth and 12% in adulthood - the face occupies less than 30% of the skull height at birth and 60% in adulthood, this demonstrates how rapidly the brain grows immediately after birth - the brain is fully grown at age 8yrs on average	

Growth patterns and post natal growth	- different tissues have different growth patterns in terms of rate and timing, described by Scammon Growth Curves (see below)  - there are 4 main types of growth patterns: 1. Neural 2. Somatic 3. Genital 4. Lymphoid - the max and mand follow a pattern of growth that is intermediate between the neural and somatic growth - differential growth as the mand follows the somatic growth curve more closely than the max	
Long-term facial growth changes	20 adults studied over 30yrs, findings: i) vertical growth continues after AP and lateral changes have ceased ii) lateral facial growth ceases prior to puberty ↑ in all dimensions between 1.01-5.53mm - an average ↑ in AFH of 1.6mm occurs in adulthood	Behrents, 1985; Lewis & Roche, 1988 Forsberg et al., 1991
Soft tissues	- soft tissues do not grow proportionately to hard tissues - soft tissue facial growth has generally similar amounts and rates irrespective of the pubertal growth spurt - pubertal subjects show ↑ annual rates of chin protrusion Growth of the lips - prior to adolescence the growth of the lips trails behind growth of the jaws - pre-pubertal group showed ↑ annual growth rates of lip prominence - lip incompetency ↓ with age - lip thickness reaches maximum during adolescence then ↓ with age Growth of the nose - growth of the nasal bone is complete by about age 10yrs - thereafter, growth is only of the nasal cartilage and soft tissues which leads to ↑ in the prominence of the nose during adolescence - AP nasal development continues in both sexes after Sk growth has subsided	Genecov et al., 1990 Primozic et al., 2017 Primozic et al., 2017 Vig & Cohen, 1979 Genecov et al., 1990
Growth prediction	- jaw growth correlates with physiological events of puberty in the same way as height so that the onset of the pubertal growth spurt coincides with a spurt in jaw growth (there will still be individual variation) - some girls demonstrate a 'juvenile' acceleration of jaw growth - dental development poorly correlates with chronological age and physiological development - pubertal growth spurt (average): - for boys = 14yrs ± 2yrs and lasts 3½yrs - for girls = 12yrs ± 2yrs and lasts 2yrs	Songra et al., 2017 Woodside, 1974 Björk & Helm, 1967 Tanner et al., 1976

	- the onset of the pubertal growth spurt correlates with a measurement of standing height using a stadiometer - maximum velocity of pubertal growth coincides with the Peak Height Velocity (PHV) - hand wrist R/Gs to establish extent of Sk development are unreliable for prediction of pubertal growth spurt - cervical vertebral bone age has been suggested as a means of predicting mandibular growth - use of cervical vertebral maturation and hand-wrist R/Gs shown to be less accurate in predicting timing of pubertal growth spurt than measuring pt's height - prediction of adult size and direction of growth of the jaws is impossible on an individual basis - individual comparison with average measurements, e.g. Bolton standards, is a possible aid but suffers from difficulties in matching for sex and race - Michigan growth study data are subdivided for sex - Burlington growth study data are subdivided for short, normal and long vertical facial dimensions - cephalometric standards for comparing facial growth are matched either for gender or race but never for both - no single method can be used to predict an individual's growth	Sullivan, 1983 Houston et al., 1979 Mito et al., 2003 Mellion et al., 2013 Houston, 1979 Johnston, 1975 Broadbent et al., 1975 Songra et al., 2017
Cervical Vertebral Maturation	- the cervical vertebral maturation method uses only C2, C3 and C4 to predict mandibular growth CVMS 1: The lower borders of C2, C3 and C4 are flat. The bodies of both C3 and C4 are trapezoid in shape. The peak in mandibular growth (PMnG) will occur on average 2yrs after this stage CVMS 2: C2 lower border is now concave. C2 and C3 are still trapezoid in shape. The PMnG will occur on average 1yr after this stage CVMS 3: The lower border of C2 and C3 are concave. The bodies of C3 and C4 may be either trapezoid or rectangular horizontal in shape. The PMnG will occur during the year after this stage CVMS 4: C2, C3 and C4 lower borders are concave. Both C3 and C4 are rectangular - horizontal in shape. PMnG has occurred within 1 or 2yrs before this stage CVMS 5: At least one of the bodies of C3 and C4 is squared in shape. The PMnG has ended at least 1yr before this stage CVMS 6: At least one of the bodies of C3 and C4 is rectangular - vertical in shape. PMnG has ended at least 2yrs before this age - progression from one cervical vertebral stage to another does not occur annually - the time spent in each stage varies, on average, from 1.5 to 4.2yrs depending on the stage - the most frequent stage at which PMnG occurs is CVMS4 - CVM method not recommended for use in isolation	Baccetti et al., 2002; Mito et al., 2003 Baccetti et al., 2005 Ball et al., 2011 Zhao et al., 2012

	- doubt has been cast on the reproducibility of this method which has been found to be poor due to difficulty in classifying the shape of bodies C3 and C4 - method found to have poor reliability and validity - with training and calibration classification can be reproducible and reliable - potential for AI and deep learning software to interpret CVM stage	Nestman et al., 2011 Zhao et al., 2012 Santiago et al., 2012 Rainey et al., 2016 Makaremi et al., 2019
Relevance of growth to orthodontic treatment	- orthodontic treatment is often quicker if growth is present - speed of tooth movement significantly ↑ in growing versus non growing individuals - although orthodontic treatment has very little influence over Sk pattern, using orthodontics alone there are more options available for treating Sk CI 2 cases than Sk CI 3, i.e. HG is less frequently used on Sk CI 3 cases and chin cups produce only a temporary correction of Sk discrepancy - maxillary sutures become more interdigitated with ↑ age, thus more difficult to separate them for growth stimulation - influence of growth on treatment, facilitating: i. OB reduction ii. distal movement of posterior teeth iii. space closure iv. occlusal settling v. functional appliance treatment vi. use of RME - influence of growth on functional treatment (see section on Functional Appliances) - direction of growth rotations influences the development and treatment of a malocclusion (see section on Growth Rotations) - average change of 0.7° in ANB angle occurs between 12 - 22yrs however 1 in 20 people will have a change of 5.2° - impossible to predict ANB change on an individual basis - residual growth in corrected Sk discrepancy cases may → relapse of OJ and OB - Xtn only treatment should be timed with a period of maximal growth in order to obtain maximum space closure - in girls this is, on average, 2yrs prior to boys so Xtns at age 14yrs will produce ↑ space closure in boys than girls, on average, because girls have passed their pubertal growth spurt - mandibular growth continues after maxillary growth for boys, whose mandibles are on average larger than girls' - orthodontics for moderate or severe Sk CI 3 cases should be delayed until the pubertal growth spurt has ceased; this is because as individual growth cannot be predicted, an individual may grow to the extent that they need orthognathic surgery	Iwasaki et al., 2017 Thilander, 1963 Proffitt et al., 2007 Stephens & Houston, 1985 Björk & Skieller, 1972 Björk & Skieller, 1972 Nanda & Nanda, 1992 Stephens & Houston, 1985; Ireland et al., 2016
Trends in growth	- evidence of year of birth effect - literature that compares growth to historical controls should be interpreted with caution	Antoun et al., 2015 Papageorgiou et al., 2017
Recommended reading	Baccetti et al., 2005; Mellion et al., 2013; Antoun et al., 2015; Songra et al., 2017	

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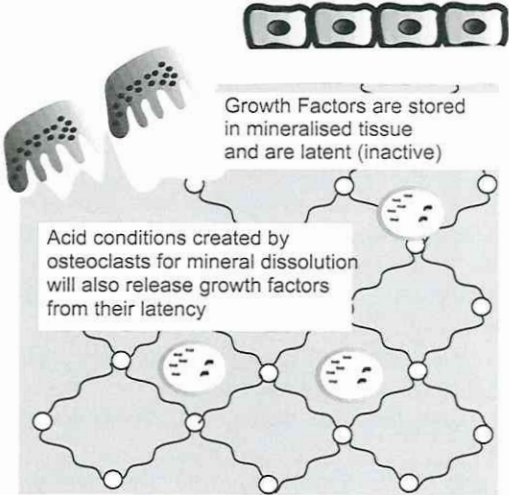
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Definition	Bone turnover refers to total volume of bone that is both resorbed and formed over a period of time, usually expressed as %/year; estimated by measuring relevant bone biomarkers Bone remodelling - an active process of resorption and formation (coupling) throughout skeleton, essential for calcium homeostasis and preserving the integrity of skeleton, through coupled activity of osteoclasts and osteoblasts; in adults, bone turnover occurs mainly through bone remodelling	Parfitt, 2002
Bone	Consists of: • inorganic mineral component, i.e. calcium hydroxyapatite (2/3 of its weight) • osteoid or organic matrix (1/3 by weight) mostly Type 1 collagen (90%) and small amounts of non collagenous proteins such as growth factors, osteonectin, osteocalcin and proteoglycans • cells - 90% of cells of osteocytes	
Cells involved	Osteoblasts • bone forming cells which line bone • arise from undifferentiated mesenchymal cells, e.g. from periodontal ligament • mesenchymal cells differentiate through the immature pre-osteoblast state to the mature, functional osteoblast state • synthesises both collagenous and noncollagenous bone proteins when mature, which constitute the organic matrix or osteoid • defects in osteoid synthesis e.g. Type I collagen, can lead to serious disorders such as osteogenesis imperfecta • produce Rank Ligand (RANKL) and are responsible for osteoclast recruitment and activation • produce Osteoprotegerin (OPG) decoy receptor for RANKL which inhibits the differentiation of osteoclasts, suppresses their activation and induces osteoclast apoptosis (cell death); these are important controls of bone remodelling • have receptors for most of the bone resorbing hormones such as parathyroid hormone, cytokines such as RANKL, prostaglandins, 1,25-Dihydroxy-vitamin D3 • this osteoblast-osteoclast interaction controls resorption • defects in osteoblast differentiation and maturation can lead to wide-ranging lethal disorders • if active, => ↑ levels of alkaline phosphatase Osteocytes • are terminally differentiated osteoblasts • osteocytes are connected with each other and surface lining osteoblasts through canaliculi • osteocytes produce sclerostin (a protein) coded for by SOST; this negatively regulates bone formation and favours resorption • mutations in SOST result in a monogenic bone disease called osteosclerosis or Van Buchem disease with excess bone deposition in long bones and the skull • sclerostin inhibits bone formation by the osteoblasts • mechanical strain and bone resorbing hormones such as PTH inhibit sclerostin formation and therefore bone formation take place, i.e. part of bone coupling • this osteocyte-osteoblast interaction is important in bone resorption and bone formation	Meikle, 2002, 2006

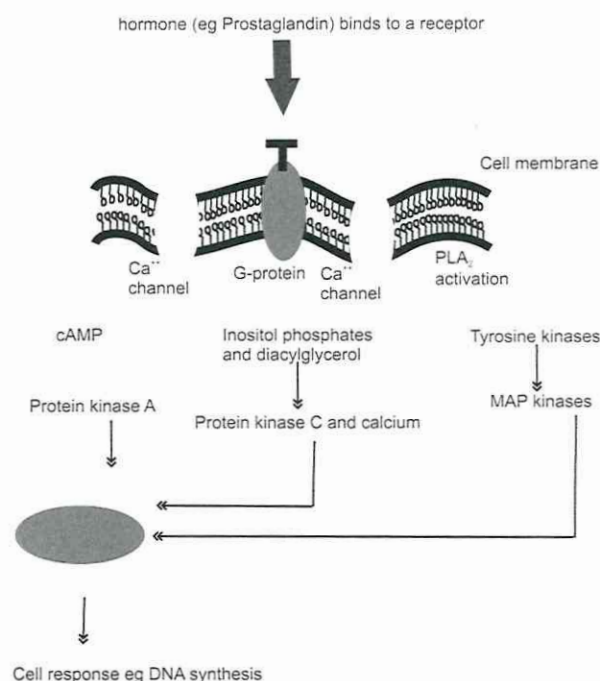
	Osteoclasts • bind to bone via integrin/protein • main bone resorption cell • arise from monocytes, e.g. from blood • multi-nucleate cell (fusion of monocyte) with ruffled border (to ↑ surface area) and receptors for specific hormones, e.g. calcitonin and retinoic acid • under direct and indirect control from hormones and growth factors • osteoclasts cannot resorb bone without prior activation by the osteoblast • principle activator of osteoclasts is RANK Ligand (RANKL), a cell surface protein expressed by osteoblasts • osteoclasts have receptors for RANKL; RANKL is also important for the differentiation of osteoclasts from monocytic precursors • if active => ↑ levels of tartarate resistant acid phosphatase	
	Osteoblasts have receptors for: Cytokines Growth factors Eicosanoids Vitamin D3 PTH RANKL MMPs produced by osteoblasts Osteocytes are pivotally placed to detect stress in bone. Osteoclast recruitment and activation M-CSF RANKL Osteoclast precursor fusion Osteoclast activation Activated osteoclast RANKL PTH or mechanical stress Osteoblast stromal cell	
Bone resorption sequence	A hormone, e.g. prostaglandin E₂ (PGE₂), binds to a receptor on the osteoblast → signal transduction plus osteoblast response Osteoblast response: 1. produces soluble mediator for activation and recruitment of osteoclast (RANKL) 2. produces matrix metallo proteinases (MMPs) for breakdown of non mineralised osteoid layer 3. once osteoid is removed mineralised matrix is exposed and osteoclasts can remove bone	Krishnan & Davidovitch, 2006
Bone Formation	• osteocytes (osteoblasts incorporated into mineralised bone matrix) are situated in a rigid matrix and are thus ideally positioned to detect changes in mechanical stresses • they can signal to surface lining osteoblasts and thus bone formation and indeed bone resorption may result • control of osteoclast cell death important in overall control of bone remodelling	

Bone Matrix	- bone is an enormous reservoir for many growth factors such as: - <i>platelet derived growth factor</i> (PDGF) - <i>insulin like growth factors I and II</i> (IGFI and IGFI) - <i>bone morphogenetic proteins</i> (BMP) - these are part of the transforming growth factor beta (TGFβ) superfamily and are important inducers of bone formation - some of these growth factors, e.g. fibroblast growth factor (FGF) are bound to heparin sulphate within bone - others such as TGFβ or IGFI have distinct binding proteins to keep the growth factors in the bone matrix - most of these growth factors are in a latent (non-active) form → acid conditions created by the osteoclasts for mineral dissolution may: a) cleave growth factors, e.g. TGFβ, from their binding proteins and b) release them from latency - bone resorption/formation are therefore to some extent dependent on each other, most control is through negative feedback directly on the osteoblasts and osteoclasts	Krishnan & Davidovitch, 2006
Growth factors and bone Osteoblasts produce growth factors.: Such as: - Platelet Derived Growth Factor - Insulin Growth Factors (I+II) - Transforming Growth Factors - Bone Morphogenetic Proteins - Fibroblast Growth Factors  Growth Factors are stored in mineralised tissue and are latent (inactive) Acid conditions created by osteoclasts for mineral dissolution will also release growth factors from their latency		
Cytokines	- ever growing family of molecules which are small proteins with either paracrine or endocrine functions - are involved in local inflammation or immunoregulation - within this definition growth factors could be included - main groups are: - <i>Interleukins</i>, e.g. Interleukin-1 - a highly potent bone resorptive agent - <i>Interferons</i> - <i>Chemokines</i> - induce cell migration - <i>Tumour necrosis factors (TNF) α</i> - <i>Macrophage colony-stimulating factor</i> - M-CSF expressed by osteoblasts - <i>RANKL</i> - expressed by osteoblasts - RANKL acts as direct stimulator of osteoclasts and its expression can be $\uparrow$ by stimulating the osteoblast - the osteoclast receptor RANK mediates RANKL's effects	Meikle, 2002, 2006 Krishnan & Davidovitch, 2006 Garlet et al., 2007 Ren & Vissink, 2008 Kong et al., 1999

	• RANKL -/- (nullizygous) mice have diminished RANKL production (so no osteoclast activity because there is no osteoblast signal) and are osteopetrotic - the osteopetrosis can be reversed by injecting RANKL protein	
Chemokines	• a superfamily of small chemotactic cytokines which regulate inflammatory processes and migration • known to be involved in cell pre-cursor development for osteoblasts and osteoclasts • osteoclast precursors express chemokine receptors and the chemotactic signals by chemokines may invoke their migration to bone tissues as well as the differentiation, survival and activation of osteoclasts (also requires involvement of RANK-RANKL) • osteoblasts express several chemokine receptors, and the binding of chemokines induces both proliferation and collagen Type I mRNA expression in osteoblasts • differential expression of chemokines in compressed and stretched periodontal ligament during orthodontic tooth movement which may create distinct microenvironments on compression and tension sides	Garlet et al., 2008
Proteoglycans	• the major extra cellular non-fibrous macro molecules • they have a protein core and carbohydrate components which are called <i>glycosaminoglycans</i> • these can be listed as follows: - Hyaluronic acid - Chondroitin sulphate - Dermatan sulphate - Heparan sulphate - Heparin - Keratan sulphate • have a unique property: most of them are able to retain water and act as 'biological' shock absorbers • useful in the periodontal ligament (PDL) which provides support to teeth during masticatory function; may well help with PDL's <i>visco elastic</i> properties seen during orthodontic loading: i.e. if pressure is placed on these macro molecules, water is displaced which moves into intermolecular spaces thus minimising intermolecular interactions and maximising water retention • significance in orthodontic tooth movement: chondroitin-4-sulphate has been pinpointed as a gingival crevicular fluid marker of bone turnover during orthodontic tooth movement	Last et al., 1988
Matrix Metallo Proteinases (MMP)	• extracellular matrix degrading metallo enzymes, called metallo because they depend on Zn⁺⁺ and Ca⁺⁺ for activity • endogenous inhibitors exist and these are called tissue inhibitors of metallo proteinases (TIMPs) • nomenclature of MMP's constantly changes • act at neutral pH and are important because they digest the major macro molecules of connective tissues • tissue breakdown occurs where MMPs are in excess of TIMP • significance in orthodontic tooth movement: MMPs and TIMP are ↑ during mechanical deformation of sutures • collagenase activity is ↑ at sites of ↑ cell proliferation and it is clear these molecules are important during orthodontic tooth movement	
Second Messengers	• also known as internal cell signalling and these pathways elicit a cell response, e.g. DNA synthesis	

	- there are three main second messenger systems which transduce signals from a cell membrane to the inside of a cell and ultimately to the nucleus, these are: i. <i>cAMP</i> - activates protein kinase A ii. <i>Inositol phosphates</i> - release intra cellular calcium from endoplasmic reticulum and also same metabolic pathway produces diacylglycerol which activates protein kinase C iii. <i>Tyrosine kinases</i> - are activated by many growth factors; activate a series of enzymes within the cytosol (mitogen activated protein kinases - MAP kinases) which will ultimately translocate to the nucleus - at the cell membrane a hormone binds to a receptor and these are often further regulated by guanine nucleotide (G) proteins - these G proteins may be inhibitory or stimulatory and act as a further control mechanism - both cAMP and inositol phosphates have been implicated during orthodontic tooth movement - the work on the involvement of prostaglandins and cyclic AMP in tooth movement formed much of the basis for the biomechanical theory	Krishnan & Davidovitch, 2006 Sandy et al., 1993
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Second Messengers



Arachidonic Acid Metabolism

- all cell membranes are made up of phospholipids
- the action of the enzyme phospholipase A2 (PLA2) cleaves arachidonic acid from these membrane phospholipids
- arachidonic acid is the substrate for cyclo and lipo-oxygenase actions
- prostaglandins are produced by cyclo oxygenase activity and lipo-oxygenase products are the leukotrienes and HETES
- initially, in vitro experiments where cells were mechanically deformed suggested that prostaglandins are mediators of mechanical stress

	• this was extended to animal models where injection of prostaglandins ↑ bone turnover adjacent to teeth being moved and furthermore blockage of prostaglandin synthesis (with non steroidal anti-inflammatory drugs) ↓ the amount of osteoclast activity • ultimately, prostaglandin E1 has been used to ↑ orthodontic tooth movement in adults • leukotrienes and HETES have also been implicated in orthodontic tooth movement	Krishnan & Davidovitch, 2006
Recommended reading	Sandy, 1998; Andrade et al., 2012	

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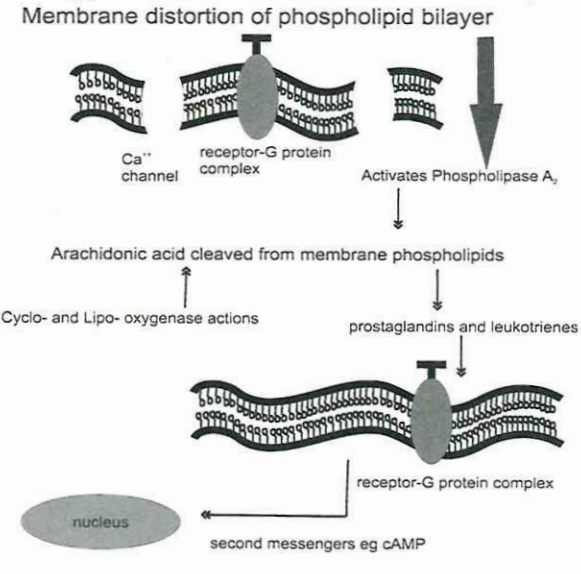
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Tooth movement	• occurs due to bone remodelling - a specific coupled sequence of resorption and formation events to replace existing bone • physiological, i.e. in response to muscular or orthodontic forces • leads to bone being laid down in tension sites and bone being resorbed at pressure sites • 4 stages of tooth movement: initial, lag, acceleration, constant • tooth movement is a highly individual response not force dependent • some surgical adjuncts show promise, however more research is needed • little evidence to support the use of non surgical adjuncts to speed up tooth movement, including vibrational forces	Meikle, 2006 Pilon et al., 1996 Pilon et al., 1996 Fleming et al., 2015 El-Angbawi et al., 2015; Woodhouse et al., 2015
Theories on tooth movement	There are four main theories regarding tooth movement: • The Biomechanical/Cellular response theory • The Piezoelectric theory • The Pressure tension hypothesis • The Hydrodynamic theory No one theory is universally accepted, but evidence is more compelling for some compared to others. There is also some overlap between theories. 1. The Biomechanical/Cellular Response Theory • distortion may arise from fluid flow from an area of compression to a zone of tension; this flow causes a strain in cells and also stretch the intracellular cytoskeleton; this is attached through the cell wall to the extra cellular matrix resulting in force on the cell membrane, the cytoskeleton and the surrounding matrix • mechanically distorting a cell membrane activates phospholipase A2 • phospholipase A2 initiates arachidonic acid metabolism • arachidonic acid metabolism activates the lipo-oxygenase pathway (leukotrienes (LT) and HETE) and the cyclo-oxygenase pathway (prostaglandins PGs) Membrane distortion of phospholipid bilayer  cell response eg DNA synthesis	Meeran, 2012 Sandy et al., 1993

	• good clinical evidence that both leukotrienes and prostaglandins have been linked to tooth movement • prostaglandins feed back to receptors on the cell membrane (G-proteins) which stimulate second messengers cascades resulting in a cellular response • not clear how tissues discriminate between tension and pressure, may be due to flattening of cells on tension side • flattened cells are anabolic (tension side) so leads to DNA synthesis, protein synthesis and collagen synthesis • rounded cells are catabolic and so destroy tissues via proteases • there are also molecules such as RANKL and sclerostin that are modified by tooth movement, but the evidence is weak and conducted in animals • RANKL increases at the pressure site thus $\uparrow$ osteoclast recruitment and activation • sclerostin is $\downarrow$ in the tension site there is therefore $\downarrow$ inhibition of osteoblast activity and more bone is formed • osteocytes are ideally placed to detect mechanical forces placed on bone • in tooth movement sclerostin expression $\uparrow$ in the compression site which favours bone resorption (sclerostin inhibits bone formation) • PDL cells are being recognised as key regulators of RANKL and sclerostin during orthodontic tooth movement • in bone loading and unloading models an $\uparrow$ loading $\downarrow$ sclerostin (thus $\uparrow$ bone formation) and $\downarrow$ load $\uparrow$ sclerostin which favours bone resorption • Wnt signalling is a key regulator of bone; Wnt 1 expression $\uparrow$ in alveolar osteocytes and PDL on the tension side (favouring bone formation); in compression sites Wnt1 is attenuated favouring bone resorption cells 2. The Piezoelectric theory (Bassett, 1965) • the basis of this theory: pressure on tooth is transferred to alveolar bone which bends in response to the pressure • the bends in the bone cause <u>small electrical charges</u> (flows along crystalline structure) which activate osteoblasts and osteoclasts resulting in the resorption and deposition needed to move a tooth through bone • because electrical fields and magnetic fields are closely linked, there is a belief that they may both play an influential role in tooth movement In favour of this theory is: • the tooth is displaced 10 times more than PDL width thus bone bending must occur • pulsed and static electric fields can $\uparrow$ the rate and amount of tooth movement • physically distorting dry bone produces piezoelectric forces Against this theory is: • PDL is unlikely to transfer forces to bone • if PDL is disrupted, e.g. in rats with disrupted collagen, normal tooth movement occurs in response to physical pressure • magnetic fields alone have little, if any, effect on tissues • in hydrated tissues, streaming potential and nerve impulses $\rightarrow$ larger electrical fields thus it is likely that piezoelectric forces may get swamped by the normal physiological electrical activity	Yamasaki et al., 1984; Mohammed et al., 1989 Odagaki et al., 2018 Robling et al., 2008 Ei Hsu Hlaing et al., 2020 McDonald, 1993 Baurmind, 1969 Farndale & Murray, 1985; Davidovitch et al., 1980 Heller & Nanda, 1979
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	3. The Pressure-Tension Hypothesis (Schwarz, 1932) - essentially Wolff's Law, in that if you put a pressure on the bone, the bone will remodel to release that pressure - metabolically active bone → electronegative charge proportional to activity so creates a bioelectric potential - these low level currents are known to stimulate skeletal repair and regeneration in response to load - due to the pressure distorting the bone, this theory has overlap with theories 1 and 2, although similar, this theory is about stress-induced changes rather than electrical signals which stimulates cellular differentiation and ultimately tooth movement - unlikely to be a major component of tooth movement but may be an initial signal in response to pressure In favour of this theory is: - the tooth is displaced 10 times more than PDL width thus bone bending must occur Against this theory is: - PDL is unlikely to transfer forces to bone - if PDL is disrupted as in rats with disrupted collagen normal tooth movement occurs in response to physical pressure - in addition, there is a belief that osteoblasts may not be able to distinguish between pressure and tension 4. The Hydrodynamic theory - perhaps the weakest theory - pressure is transmitted via the cells of the PDL, the vessels (lymph and blood) and the interstitial fluid to the bone; causing it to remodel Against this theory is: - PDL system is not a 'closed box', i.e. it is open at the top	Baumrind, 1969 Heller & Nanda, 1979																											
Physiological response to sustained pressure	<table border="1"> <thead> <tr> <th>Time</th><th>Light pressure</th><th>Heavy pressure</th></tr> </thead> <tbody> <tr> <td><1 sec</td><td>PDL fluid compressible → alveolar bone bending → signal release</td><td>PDL fluid compressible → alveolar bone bending → signal release, pain</td></tr> <tr> <td>1-2 sec</td><td>PDL fluid expressed, tooth moves in PDL space</td><td>PDL fluid expressed, tooth moves in PDL space</td></tr> <tr> <td>3-5 sec</td><td>Blood vessels in PDL partly compressed on pressure side, dilated on tension side → PDL fibres/cells mechanically distorted</td><td>Blood vessels occluded on pressure side</td></tr> <tr> <td>Minutes</td><td>Blood flow altered, O₂ tension changes, prostaglandins and cytokines released</td><td>Blood flow cut off to compressed PDL area</td></tr> <tr> <td>Hours</td><td>Metabolic changes occur: chemical messengers → cellular activity Enzyme level change</td><td>Cell death in compressed PDL area</td></tr> <tr> <td>~4 hrs</td><td>↑ cAMP levels detectable, cellular differentiation begins within PDL</td><td>Cell differentiation in adjacent bone spaces → beginning undermining resorption</td></tr> <tr> <td>~2 days</td><td>Tooth movement begins as osteoblasts/clasts remodel bony socket</td><td>Cell differentiation in adjacent bone spaces → beginning undermining resorption</td></tr> <tr> <td>7-14 days</td><td></td><td>Undermining resorption removes lamina dura adjacent to PDL; tooth movement occurs</td></tr> </tbody> </table>	Time	Light pressure	Heavy pressure	<1 sec	PDL fluid compressible → alveolar bone bending → signal release	PDL fluid compressible → alveolar bone bending → signal release, pain	1-2 sec	PDL fluid expressed, tooth moves in PDL space	PDL fluid expressed, tooth moves in PDL space	3-5 sec	Blood vessels in PDL partly compressed on pressure side, dilated on tension side → PDL fibres/cells mechanically distorted	Blood vessels occluded on pressure side	Minutes	Blood flow altered, O ₂ tension changes, prostaglandins and cytokines released	Blood flow cut off to compressed PDL area	Hours	Metabolic changes occur: chemical messengers → cellular activity Enzyme level change	Cell death in compressed PDL area	~4 hrs	↑ cAMP levels detectable, cellular differentiation begins within PDL	Cell differentiation in adjacent bone spaces → beginning undermining resorption	~2 days	Tooth movement begins as osteoblasts/clasts remodel bony socket	Cell differentiation in adjacent bone spaces → beginning undermining resorption	7-14 days		Undermining resorption removes lamina dura adjacent to PDL; tooth movement occurs	
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Theories of tooth eruption	Pulp theory - pulp propels the tooth upwards - evidence against: - if pulp is removed tooth still erupts																												

Faster tooth movement	Surgical methods • corticotomy • microperforations • piezocision has been suggested but no evidence ↑ rate of tooth movement and risk of damage to roots • may result in faster canine retraction but no evidence on the effect on overall treatment time Non-surgical methods • vibrational stimulation ↑ tooth movement • vibrational stimulation does not ↑ tooth movement • systemic administration of PGs ↑ canine retraction • parathyroid hormone ↑ tooth movement • low level laser phototherapy - systematic review found low density lasers give more effective tooth movement; high levels ↓ tooth movement - thought to ↑ motility and velocity of RANKL macrophages • difficult to exclude cross over effect so split mouth trial results should be interpreted with extreme caution	Uribe et al., 2017 Fleming et al., 2015 Nishimura et al., 2008 Woodhouse et al., 2015 Yamasaki et al., 1984 Soma et al., 2000 Ge et al., 2015 El-Angbawi et al., 2015
Recommended reading	Craddock & Youngson, 2004; Roberts-Harry & Sandy, 2004	

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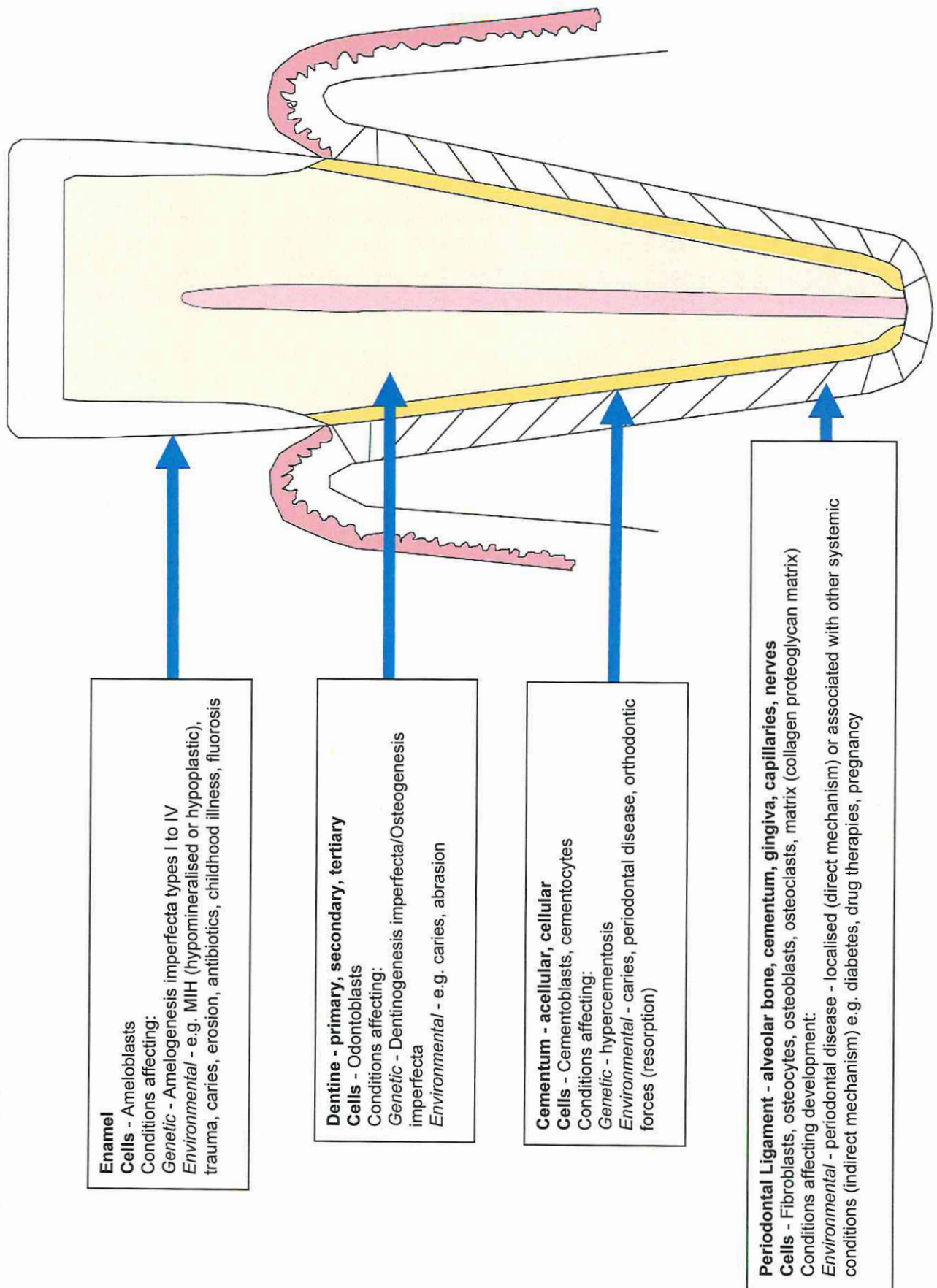
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Chronology of Tooth Development

Tooth	Tooth germ fully developed	Dentine formation begins	Calcification begins	Crown formation complete	Appearance in oral cavity	Root complete
Primary						
Incisors	3 - 4 mths i.u.l.	4 - 6 mths i.u.l.		2 - 3 mths 9 mths	6 - 9 mths 16 - 18 mths	1 - 1.5 yrs after appearance in the mouth
Canines				6 mths 12 mths	12 - 14 mths 20 - 30 mths	
1 st Molars						
2 nd Molars						
Permanent						
Upper centrals	30 th week i.u.l.	3 - 4 mths	3 - 4 mths	4 - 5 yrs	7 - 9 yrs	2 - 3 yrs after appearance in the mouth
Lower centrals		10 - 12 mths	10 - 12 mths		6 - 8 yrs	
Upper laterals		3 - 4 mth	3 - 4 mths		7 - 9 yrs	
Lower laterals		4 - 5 mths	4 - 5 mths	6 - 7 yrs	6 - 8 yrs	
Upper canines	30 th week i.u.l.				11 - 12 yrs	2 - 3 yrs after appearance in the mouth
Lower canines					9 - 10 yrs	
Upper 1 st premolar	30 th week i.u.l	1.5 - 2.5 yrs	1.5 - 1.75 yrs	5 - 6 yrs	10 - 11 yrs	2 - 3 yrs after appearance in the mouth
Lower 1 st premolar			1.75 - 2 yrs		10 - 12 yrs	
Upper 2 nd premolar			2 - 2.25 yrs	6 - 7 yrs	10 - 12 yrs	
Lower 2 nd premolar			2.25 - 2.5 yrs		11 - 12 yrs	
1 st molar	24 th week i.u.l.	Before birth	At or shortly after birth	2.5 - 3 yrs	6 - 7 yrs	2 - 3 yrs after appearance in the mouth
2 nd molars	6 th mth	2.5 - 3 yrs	2.5 - 3 yrs	7 - 8 yrs	11 - 13 yrs	
3 rd molars	6 th yr	7 - 10 yrs	7 - 9 yrs	12 - 16 yrs	17 - 21 yrs	

i.u.l. = intra-uterine life

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Craniofacial Anomalies

Craniofacial Syndromes

Clefts

Craniofacial Syndromes

Types	Too many to list all (refer to text) Craniosynostoses • Apert's syndrome • Crouzon's syndrome • Pfeiffer's and Apert's have defects in the fibroblast growth factor receptor 2 (FGFR2) gene Orofacial clefting syndromes • Cleft lip and palate • Pierre-Robin syndrome • Tessier facial clefts Branchial arch disorders • Di George's syndrome • Craniofacial microsomia • Mandibulofacial dysplasia (Treacher Collins syndrome) • Pierre-Robin sequence • Oro-facial-digital syndrome Syndromes affecting bone/cartilage • Achondroplasia • Cleido-cranial dysplasia Others • Binder's syndromes (maxillonasal dysplasia) • Foetal alcohol syndrome (FAS)	Gorlin et al., 1990 Akram et al., 2015
Embryology	• neural tube formation and subsequent neural crest cell migration very important in craniofacial development • defects in these stages thought to lead to development of many craniofacial syndromes	
Craniosynostoses		
Apert's syndrome	• autosomal dominant • craniosynostosis of coronoid and lambdoid sutures; other sutures can still grow leading to abnormal skull shape • hypertelorism • syndactyly of hand and feet (soft tissues and bone) • turribrachycephaly and high steeped forehead • proptosis • midface hypoplasia • high arched palate • CI III malocclusion and AOB • delayed eruption • CP • defect in the FGFR2 gene	Vargervik et al., 2012
Crouzon's syndrome	• autosomal dominant • craniosynostosis of coronoid, sagittal and lambdoid sutures • mid-face hypoplasia and frontal bossing • hypertelorism and proptosis • maxillary hypoplasia • CI III malocclusion • max crowding and V-shaped max • high arched palate • small and missing teeth • CP (3%) • differential diagnosis - Apert's has syndactyly	Vargervik et al., 2012
Orofacial Clefts		
Cleft Lip & Palate	• see section on Cleft Lip and Palate	Dixon et al., 2011
Pierre-Robin syndrome (PRS)	• triad of clinical signs: retrognathic mand/glossoptosis/respiratory distress +/- CP	Mackay, 2011

	• may occur in isolation or associated with other syndromes • immediate concerns relate to airway and feeding • some 'catch-up' growth achieved	
Tessier facial clefts	• classification for rare and atypical craniofacial clefts and latero-facial (oblique) clefts with the orbit use a primary structure for reference • 15 different locations classified by Tessier	Tessier, 1976
Branchial Arch Syndromes		
Di George's Syndrome - Velocardiofacial syndrome (22q11.2 deletion syndrome)	• most common microdeletion syndrome • embryonic insult during 4th to 7th week IU • range of features with craniofacial anomalies (60%) • absence/hypoplasia of thymus ± parathyroid glands (mild cases) • cardiovascular anomalies (more severe cases), only 5% of pts have normal hearts • craniofacial anomalies (60%) • micrognathia • deep, low-set, small ears • blunted and cleft nose • hypertelorism • high arched palate and dental anomalies • ± CP/bifid uvula	Dalben et al., 2010 Klinberg et al., 2002
Oculo-auriculo-vertebral Spectrum (Goldenhar Syndrome, 1st Arch Syndrome, 2nd Arch Syndrome, Craniofacial/Hemifacial microsomia - HFM)	• variable spectrum of presentation involving primarily aural, oral, mandibular development • most commonly unilateral effects • possible pathogenic HFM models include vascular abnormality/haemorrhage in the craniofacial region, damage to Meckel's cartilage and the abnormal development of cranial neural crest cells • deformities of pinna, microtia, ± ear tags/deafness • narrowing of palpebral fissure • vertical dislocation of orbit • agenesis/hypoplasia of mandibular ramus • AP and vertical dimensions reduced on affected side • CL ± CP (7-15%) • delayed tooth eruption • associated with heart and lung defects • OMENS classification of hemifacial microsomia exists	Akram et al., 2015 Vargervik, 1998 Vento et al., 1991
Mandibulofacial dysplasia (Treacher - Collins syndrome - TCS)	• autosomal dominant inheritance (variable expression) • mutation of TCOF1 gene and production of truncated TREACLE protein • two other genes implicated POLRIC and POLRID in rarer forms of TCS • involves structures of 1st and 2nd arch • deficient cranial neural crest formation and proliferation as well as mass apoptosis • malar and zygomatic hypoplasia (arches may be absent) • downwards sloping palpebral fissures due to incomplete orbital rims • ear defects including auditory canal stenosis/atresia incomplete or missing middle ear ossicles, microtia or anotia (total absence of outer ear) ± deafness • micrognathia and retrognathia with receding chin and hypoplastic condyle • Sk CI 2 with ↑ vertical proportions and post growth rotation with AOB • dental anomalies including tooth agenesis, ectopic eruption and enamel defects • CP (35%)	Dixon, 2006 Arvystas & Shprintzen, 1991 Posnick & Ruiz, 2000 Dalben et al., 2006

	• large down turned mouth • associated with cardiac defects, airway obstruction, mastication and speech	
Oro-facial-digital syndromes	• Types I - VIII, all with similar features • frontal bossing, euryopia, hypoplasia of alar cartilages • zygomatic hypoplasia • pseudocleft of midline of upper lip (45%) • CP - SP (80%) • digital anomalies: brachydactyly, syndactyly, polydactyly • tongue hamartomas, clefts or lobulations • fraenal hyperplasia • supernumeraries and hypodontia • other features present depending on type	
Achondroplasia	• autosomal dominant inheritance • most common skeletal dysplasia • defective development of endochondral ossification • around 4 feet tall on average • frontal bossing and depressed nasal bridge • midface hypoplasia • CI III malocclusion • defect appears to be in the FGFR3 gene • achondroplasia is a misnomer because there is always some cartilage present	Pineau et al., 2018
Cleido-cranial dysplasia	• autosomal dominant inheritance • RUNX2 mutation • defective development of intramembraneous ossification - absent (in around 10%) or vestigial clavicles • short stature • delayed closure of fontanelles and multiple wormian bones • brachycephalic skull • frontal bossing • hypertelorism • midface hypoplasia • $\pm$ CP • high arched palate • multiple supernumeraries associated with delayed eruption - can get a 'tertiary dentition' • no cementum on teeth	Becker et al., 1997
Binder's syndrome	• nasomaxillary hypoplasia (arhinoid face) • no ant nasal spine and thin alveolar plate around upper incisors • hypoplastic premaxilla • CI III malocclusion • absence of frontal sinus	Defraia et al., 2012
Foetal alcohol syndrome	• aetiology - exposure to high level of alcohol $\rightarrow$ deficiency of neural plate midline tissue • narrow forehead • short palpebral fissures • small nose and midface • long/thin upper lip, indistinct philtrum • micrognathia • minor ear anomalies	Sant'Anna & Tosello, 2006
Gardner's syndrome	• osteomas • multiple supernumerary teeth • ortho implication: $\uparrow$ bone density, hypercementosis, presence of osteomas $\rightarrow$ Xtn and orthodontic tooth movement are more difficult	Baldino et al., 2019

	• intestinal adenomatous polyps → malignant transformation → colorectal cancer	
Craniofacial units	• four units in the UK: Great Ormond Street (London), Oxford (John Radcliffe), Birmingham and Liverpool (Alderhey)	
Recommended reading	Gorlin et al., 1990; Akram et al., 2015; Bartzela, 2019	

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Clefts

Incidence	• most common cranio-facial abnormality • 1 in 700 live births in UK • unilateral CLP 21% CL 20% CP 40% bilateral CLP 11% Others, e.g. submucous cleft 8% • CP often associated with syndromes • sex distribution: unilateral CLP male : female 2:1 CP male : female 2:3 CL male : female 2:1 • racial bias: Japanese > Caucasian > Afro-Caribbean • unilateral clefts more common on left (L:R → 2:1) • 15% of clefts associated with other syndromes	Gorlin et al., 1971 Coupland & Coupland, 1988 Medina et al., 2019 Gorlin et al., 1971
Aetiology	• unknown - polygenic, multifactorial • approx. 70% CLP cases are non-syndromic and aetiology not well understood • genes linked to clefting: • Interferon Regulatory Factor 6 (IRF6) mutation; MSX1; fibroblast growth factors (FGF/FGFR) and bone morphogenic protein-4 (BMP4) • environmental, e.g. retinoids, anti-folate drugs, temperature, hypoxia, seasonal, maternal smoking and alcohol consumption (first trimester), diet, Vit B6 deficiency	Cobourne, 2004 Dixon et al., 2011 Proetzel et al., 1996; Jezewski et al., 2003; Riley & Murray, 2007; Rahimov et al., 2008; Suzuki et al., 2009 Romitti et al., 1999; Murray, 2002; Little et al., 2004; De La Vega & Martinez, 2006; Mossey et al. 2009; Dixon et al., 2011
Genetic risks	• Unaffected parents with 1 affected child - risk of next child being affected: CLP 1:25 (4%), CP 1:80 • 1 affected parent - risk of first child being affected: CLP 1:50 (2%) • 1 affected parent and first child - risk of second child being affected: CLP 1:10 (10%) • 2 affected parents - risk of first child being affected: CLP 3:5 (60%)	
Prenatal diagnosis	• ultrasound (US) has been used for 20yrs • CL picked up more often than CP • due to head position and small size of the face, not usually reliable until at least week 15 • specificity is ↑, sensitivity is generally ↓ averaging only 20% • even within a group identified as 'at risk' for craniofacial malformations, the sensitivity is only 38% • 3D US - newer, more sensitive but less widely used diagnostic tool • Colour Doppler US - visualises abnormal flow of amniotic fluid from mouth into nasal cavity has been described	Christ & Meininger, 1983 Johnson & Sandy, 2003 Pilu et al., 1986 Michailidis et al., 2001 Monni et al., 1995
Classification	Veau • soft palate, soft and hard palate, unilateral, bilateral CLP Kernahan and Stark • based on embryology <i>clefts of 1° palate</i> - alveolus up to incisive foramen <i>clefts of 2° palate</i> - soft and hard palate, up to incisive foramen <i>clefts of 1° and 2° palate</i> - complete/incomplete, unilateral/bilateral	Veau, 1931 Kernahan & Stark, 1958

	Descriptive • now more commonly used, e.g. LAHSAL classification	Hodgkinson et al., 2005
Problems of pts with CLP	• feeding • hearing • speech • disruption of facial growth • disruption of dental development • dental anomalies, e.g. supernumeraries • dental caries • psychosocial • morbidity and mortality associated with treatment	Semb, 1991 McCance et al., 1990 Tannure et al., 2012 Worth et al., 2017 Hunt et al., 2005
Features of unoperated clefts subjects	Skeletal • normal maxillary developmental potential • max more anteriorly positioned than non-cleft individuals • some degree of 1° hypoplasia • mandibular growth ↓, i.e. smaller sized mands than non-cleft individuals • some report ↑ MMP angle Dental • hypodontia • supernumeraries • hypoplasia • microdontia • delayed eruption of teeth on cleft side • ↑ incidence of ectopic canines • ↑ incidence of impacted 6, 4x non-cleft population, unrelated to cleft side • normal incidence of range of malocclusions • ↑ incidence of crossbites (19%)	Mars & Houston, 1990 Liao & Mars 2005a,b, 2006a,b Cronin & Hunter, 1980 Tannure et al., 2012 McCance et al., 1990 Bjerklin et al., 1993 McCance et al., 1990
Features of operated clefts subjects	Skeletal • <i>lip surgery</i> - minimal effect on facial growth, ↓ width of cleft by soft tissue moulding • <i>hard palatal surgery</i> - maxillary retrusion due to scar tissue • <i>soft palatal surgery</i> - minimal effect on facial growth • <i>other problems</i> - fistulae, nasopharyngeal incompetence Dental • ↑ incidence of crossbites - 96% of pts with anterior and posterior crossbites • ↑ incidences of crowding	Mars & Houston, 1990 Dahl & Hanusardóttir, 1979 Nyström & Ranta, 1989
Aim of treatment	• to improve function and aesthetics	Mølsted, 1992
Management	Team approach: plastic surgeon orthodontist speech therapist oral maxillofacial surgeon psychologist specialist nurse ENT surgeon audiologist paediatrician geneticist	
Treatment	See Table	
Methods of assessment	Various methods of assessment surgical outcome: R/Gs • lateral and posteroanterior views • standardisation can be achieved • allows assessment of soft and hard tissues • difficult to identify points on max • radiation exposure necessary Study Models • non-invasive, no radiation exposure • standardisation can be achieved	Jones et al., 2014 Mølsted et al., 1992, 1993 Bongaarts et al., 2008

	• hard tissue assessment • Goslon Yardstick - records of 10yr old pts, ranking system, 1 (excellent outcome) → 5 (very poor outcome) • 5 Year Olds' Index - records of 5yr old pts, ranking system, 1 (excellent outcome) → 5 (very poor outcome) • 5 Year Olds' Index can be used in conjunction with photographs • refinement of 5 Year Olds' Index suggested to allow ↑ differentiation between better categories • 3D digital models are a viable alternative; intra-oral scanners may negate need for impressions Photographs • non-invasive, no radiation exposure • standardisation is more difficult although scales have been devised to assess facial appearance • silhouette lateral views used to assess surgical outcome	Mars et al., 1987, 1992 Atack et al., 1997a,b McAuliffe et al., 2010 Mittal et al., 2019 Chawla et al., 2013 Asher-McDade et al., 1991, 1992 MacKay et al., 1994
Factors influencing surgical outcome	• surgeon • surgical technique used • timing of surgery	Shaw et al., 1992a, Ross, 1987
Problems with research	Unoperated • small numbers to study • poor/no controls • wide age range • mix of cleft types Operated • many retrospective • many variables • poor/no controls • small numbers	Roberts et al., 1991
CSAG study 1998	• national study of care and outcomes of children with unilateral CLP in the UK • 2 cohorts of children, 5 and 12yr olds Findings • 57 active cleft teams in UK • lack of high volume surgeons, majority of 75 surgeons operate on < 1 unilateral CLP case/yr • did not entirely resolve relationship between volume and outcome but some strong evidence of improved speech outcomes in pts of high volume surgeons • dental arch relationship by Goslon Yardstick and 5 Year Olds' Index 37-39% of both groups either poor/very poor • 70% of 12yr olds Sk CI 3 • 42% of bone grafts severely defective or failed • dental treatment for active caries in 40% of 5yr olds, 20% of 12yr olds Recommendations • centralisation of cleft care to 8-15 centres, this would allow meaningful audit of outcome • cleft centres must ensure full range of clinical skills are available • improvement in record keeping and minimum data sets • training programmes for all cleft clinicians in approved cleft centres only	Sandy et al., 1998 Williams et al., 1999 Bearn et al., 2001; Sandy et al., 2001; Sell et al., 2001; Williams et al., 2001
Recommended minimum data sets from CSAG	• facilitate inter-centre audit • reduce pt exposure to unnecessary R/Gs • avoid unnecessary duplication of records	Report of CSAG committee
Implementation of changes	• implementation of change following CSAG challenging • 57 units providing cleft care have been ↓ to 11 managed clinical networks with 17 primary operative sites	Sandy, 2003 Scott et al., 2015

	• additional cleft surgery training pathways have been put in place • recent repeat national audit has been undertaken to review effect of changes (Cleft Care UK Study)	Persson et al., 2015
Cleft Care UK Study (CCUK)	• CCUK study replicating CSAG study to compare outcomes • dentoalveolar outcomes improved >50% in category 1 or 2 of 5 Year Olds' Index • facial appearance improved slightly • no improvement in hearing and dental health outcomes • speech improvement compared to CSAG • improved perceptions of child outcomes but no difference to parental satisfaction	Persson et al., 2015 Al-Ghatam et al., 2015 Smallridge et al., 2015 Sell et al., 2015 Waylen et al., 2015
Recommended reading	Overall treatment and research • Shaw & Semb, 1990; Roberts et al., 1991; Mølsted, 1992 Surgery • Timing - Ross, 1987 • Techniques - Boyne & Sands, 1972; Bergland et al., 1986; Ross 1987; Roberts-Harry & Sandy, 1992; Guo et al., 2011 Outcomes • Ross, 1987; Eurocleft study 1992 (Asher-McDade et al., Mars et al., Mølsted et al., Shaw et al., a&b); Sandy & Roberts-Harry, 1993; Kindelan et al., 1997; Kindelan & Roberts-Harry, 1999; Flinn et al., 2006; Deacon et al., 2007 • CSAG: Sandy et al., 1998 • Eurocleft study: Shaw et al., 2005 • CCUK: Persson et al., 2015; Al-Ghatam et al., 2015, Smallridge et al., 2015, Sell et al., 2015, Waylen et al., 2015, Ness et al., 2015 Orthodontic Treatment • Shaw and Semb 1990; Long et al., 2000 Infant Presurgical Orthodontics • Pahl et al., 2005; Pahl-Andersen et al., 2008; Bongaarts et al., 2006; Masarei et al., 2007; Bessell et al., 2011 Speech • Witzel et al., 1984; Sell & Grunwell, 1990 Psychological Effects • Strauss & Broder, 1991; Turner et al., 1998, Hunt et al., 2005 Genetics • Cobourne, 2004; Mossey et al., 2009	

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Timing	Surgery	Orthodontic	Speech
Pre-natal/ At birth	40-50% picked up at pre-natal screening before birth Counselling and information for parents Neonatal repair undertaken by some Regular hearing/ENT checks until adulthood	Records Counselling and advice on: - feeding - soft bottles, e.g. Soft Plas, with modified teats e.g. Haberman, ± feeding plate - oral health - fluoride supplements, oral hygiene Pre-surgical orthopaedics if undertaken	Counselling on speech development
3mths	Lip repair - straight line e.g. Veau, Le Measurier (can → notching of vermillion) - Z-plasty e.g. Millard (gives best scar - most commonly performed), Tennison (gives fuller lip) Alveolar repair - Vomer flap (1° bone grafting, not recommended)	Continued advice on: - oral health - feeding: - squeezable bottles easier to use than hard bottles (Bessell et al., 2011) - weak evidence to support breast feeding over spoon feeding following cleft surgery (Bessell et al., 2011)	
6mths	Palate repair (only soft palate) - Von Lagenbeck 6-18mths (↓ scarring) - Veau (lengthens palate but ↑ scarring) - Delaire (lip and SP repair undertaken at 6 mths)		
2-10yrs	± Pharyngoplasty to improve velopharyngeal competence	Further advice on oral health and regular care Records at age 5yrs	Age 2-3yrs pre-school assessment Assessment and treatment as required with 50% requiring speech therapy
7-10yrs	Secondary alveolar bone grafting No evidence for best technique (Guo et al., 2011)	Preparation for alveolar bone grafting - expansion (Quad / Tri-helix) ± anterior alignment if necessary; stabilise archform Maintain oral hygiene Records at age 10yrs	
11-15yrs		Conventional orthodontic treatment Records at age 15yrs	
18+yrs	Osteotomy (if necessary) Rhinoplasty (if necessary)	Presurgical orthodontics if necessary Records at age 20yrs Bridge and denture work as necessary	
Comment	Contest between growth and speech : - surgery restricts growth but aids speech development - no surgery allows good growth but poor speech development	Problems with stability particularly expansion maintenance	Ultimately 80% will have good speech

Anomalies

Hypodontia

Impacted Upper Canines

Supernumeraries

Unerupted Permanent Incisor

Transpositions

Double Teeth

Primary Failure of Eruption

Ectopic Eruption of Permanent First Molars

Molar-Incisor Hypomineralisation (MIH)

Infraocclusion of Primary Teeth

Hypodontia

Definition	- the developmental absence of one or more teeth, excluding 8s - classed in relation to number of absent teeth: mild ≤ 2, moderate $>2 - \leq 6$, severe >6	Goodman et al., 1994 Hobkirk et al., 1995
Prevalence and Incidence	- incidence 6.4% population (excluding 8s); mild 81.6%, moderate 14.3%, severe 3.1% - varies in different areas of world: Africa (13.4%) > Europe (7%) > Asia (6.3%) > North America (5%) > Caribbean/Latin America (4.4%) 5.3 - 5.6% UK population - females > males - similar in max and mand	Khalaf et al., 2014 Khalaf et al., 2014 Polder et al., 2004 Polder et al., 2004
General features	- associated with microdontia and ectopic canines - associated with syndromes: Down's, ectodermal dysplasia, CLP, hemifacial microsomia - most affected permanent teeth: 25-35% of all third molars 3% of all 5s 2% 2s < 1% mandibular incisors - left > right - genes involved - MSX1 (incisor, premolar), PAX9 (molar) and AXIN2 - demonstrated to have adverse impact on quality of life measures	Graber, 1978; Peck et al., 1996 Wisth et al., 1974 Cobourne, 2007 Wong et al., 2006; Akham et al., 2011, 2013
Presentation	- delayed/asymmetric eruption of permanent teeth - retained or infraoccluded primary teeth - absent primary tooth - conical/reduced crown morphology of permanent teeth present	Gill & Barker, 2015
General treatment principles	- combined planning, orthodontics/restorative opinions necessary Options: - accept residual spacing - reopen space - close space - redistribute space Decision: - maintain/open space for prosthesis or close space? - factors to consider: - malocclusion and extent of hypodontia - dental features - size, shape, colour of teeth, smile line - pt's opinion - pt's co-operation	Stevenson et al., 2013; Gill & Barker, 2015; Westgate et al., 2019 Hobkirk et al., 1995 Grahnén, 1956
Complications/ difficulties with treatment	- anchorage 'necking'/atrophy of bone - root parallelism for implants - aesthetics - risk of relapse, e.g. spaces reopening - long treatment time - cost	
Absent maxillary lateral incisor	2% population - familial tendency for both peg and missing laterals - anomalous (microdont) laterals are associated with palatally ectopic canines	Zilberman et al., 1990 Brin et al., 1986

Absent premolars	• premolars can form as late as 9yrs • lower 5s most commonly absent (2.6%), followed by upper 5s then 4s	Wisth et al., 1974
Absent lower incisor	• more common in Asian populations	Davis, 1987
Treatment options	Absent 2/2 • consider Xtn C/C to encourage 3/3 to erupt into 2 position Absent 5's • depends on crowding - spaced/aligned arch: preserve E - crowding: Xtn of E's when appropriate • for maximum spontaneous space closure Xtn E's at 9yrs • if E's survive until 20yrs then they appear to have a good prognosis for long term survival	Bjerklin & Bennett, 2000 Lindqvist, 1980 Bjerklin & Bennett, 2000
Aspects of treatment	• preferred option - space closure if aesthetics will be good (no restorative burden) • interceptive 1° Xtns for maximum spontaneous space closure • no significant difference (periodontal status, occlusion, aesthetics) between opening or closing spaces except slightly ↓ papilla fill with implant supported prosthesis • when bilateral 2s missing slightly ↑ attractiveness rating for space closure than prosthetic replacement • decision to open/close space depends on age, crowding, severity of hypodontia, attitude of family • long term periodontal studies suggest that space closure is preferable to space opening • 3/3 replacing 2/2 may require occlusal adjustments to avoid interferences (note this view precedes the now popular use of acid-etch bridges) • recontouring 3 crowns has been advocated • space maintenance/redistribution of space for a prosthesis may be preferred because of poor aesthetics related to unsuitable colour, position or anatomy of adjacent teeth • determine space required by golden proportion, contra lateral-tooth size or Bolton analysis • resin bonded bridges are a good option, survival of >80% over 6yrs, survival of cantilevered RBB at least as good as fixed-fixed design • consider preserving alveolar bone by retaining the 1° teeth for future placement of implants (once growth has ceased) • use reverse pull HG if necessary to close spaces • use of TADs has ↑ treatment options in these cases • combine treatment planning with trial wax set ups • prolonged retention for all cases • retained primary molars with missing successors the more critical prognostic factor is infraocclusion than root length • infraocclusion 25-43.5%	McNeil & Joondelph, 1973 Lindqvist, 1980 Silveira et al., 2016 Qadri et al., 2016 Robertsson & Mohlin, 2000; Rosa et al., 2016 Nordquist & McNeil, 1975 Thordarson et al., 1991 Asher & Lewis, 1986 Bolton, 1958; Spear, 1997 Creugers et al., 1992; Hussey & Linden, 1996; Probst et al., 1997 Thilander et al., 1994 Thilander et al., 2001 Goodman et al., 1994 Mizrahi & Mizrahi, 2007; Yanosky & Holmes, 2008 Asher & Lewis, 1986 Goodman et al., 1994 Hvaring et al., 2014 Laverty et al., 2018
Advantages - space opening	• space closure may be slower than space opening although treatment times found to be similar and initial crowding influences results • may not be possible to close the space completely • advantageous both functionally and occlusally, favouring good intercuspation in the buccal segments • maintains or creates canine guidance in missing 2 cases	Seehra et al., 2020 Carter et al., 2003 Balshi, 1993 Westgate et al., 2019

Disadvantage - space opening	- commits the pt to a permanent prosthesis - lengthier treatment time	Carter et al., 2003 Westgate et al., 2019
Treatment mechanics (missing 2)	Space opening - fixed appliances - for 3-dimensional tooth control 'push-pull' mechanics - involving open-coil spring in the 2 region (the 'push') and lacebacks/power chain to retract the canine (the 'pull') - minimum space requirement for implant retained prosthesis = 6.5mm (3.5mm implant needing 1.5mm space either side) - long cone PA needed to check for root angulation and measure inter-coronal/inter-radicular distance prior to debond - once appropriate space has been opened, closed-coil spring or an acrylic tooth attached to the orthodontic archwire via a bonded bracket should be placed to maintain space - retention - VFRs (can prevent relapse in all 3 dimensions) or Hawley-type retainer incorporating prosthetic teeth and wire stops; definitive restoration should take into account the need for long-term retention Space closing - invert 3 bracket (convert -7° to +7°) or bond 2 bracket to the 3 - will torque the 3 root palatally, ↓ 3 eminence and locating the root in a similar position that should have been occupied by the 2 - subtle orthodontic movements may include: - additional palatal root torque for the 3 - mesial rotation of the 4 for aesthetics (bond 4 more distally) 3 extrusion to allow the gingival margin to be positioned more incisally to mimic that of the 2 - can add buccal root torque to 4's to mimic canine eminence - retention - bonded wire retainer - space closing considered more aesthetic as space opening aesthetics dependent on restorative work quality	Savarrio & McIntyre, 2005 Richardson & Russell, 2001 Thickett et al., 2007 Rosa & Zachrisson, 2001 Shroff et al., 1996 Qadri et al., 2016
Treatment mechanics (missing 5)	Space opening - maintain lower E long-term but consider ↓ mesial-distal width (premolarise) - check E's root morphology Space closing - may be incorporated into 'Xtn' pattern if malocclusion dictates, e.g. crowding present, ↑OJ - consider controlled sectioning of lower E's to allow bodily space closure (hemisectioning), better success <9yr	Bjerklin & Bennett, 2000 Valencia et al., 2004
Long-term success of replacements	Bridges - survival 5yrs 91%, 10yrs 83% Implants 5 years - 95.2%, 10yrs 80% but complications in 24%	Thoma et al., 2016 Pjetursson et al., 2012
Recommended reading	Goodman et al., 1994; Carter et al., 2003; Khalaf et al., 2014; Gill & Barker, 2015; Silveira et al., 2016	

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Impacted Upper Canines

Definition	A canine that is prevented from erupting into its normal functional position by bone, tooth or fibrous tissue	
Incidence	- developmentally absent <u>3</u>'s: 0.08% - impacted <u>3</u>'s: 2% - palatal: 61%; in line of arch: 34%; buccal: 4.5% - unilateral: bilateral = 4:1 - F:M = 70%:30% 12.5% root resorption diagnosed using 2D R/Gs BUT 45% showed CT, F > M ↑ incidence associated with CI II/2 malocclusions	Brin et al., 1986 Ericson & Kurol, 1986 Stivaros & Mandall, 2000 Mossey et al., 1994 Ericson & Kurol, 1987, 2000 Mossey et al., 1994
Eruption	- calcification commences at 4-5mths - crown formation complete by the age of 5 - upper erupts 11-12yrs (lower erupts 9-10yrs) <u>3</u>'s palpable in buccal sulcus by 10yrs old - suggestion that ectopic <u>3</u>s are associated with delayed dental development	Ferguson, 1990 Becker & Chaushu, 2000
Aetiology	<i>Multifactorial</i> - long path of eruption - earlier development than adjacent <u>2</u>s - small or developmentally absent lateral incisors in 42.6% of cases - when anomalous <u>2</u>s present incidence x3 more common ?guidance influence of root on erupting <u>3</u> - Cs resistant to resorption - polygenic inheritance - crowding/shortening of the length of the arch - palatal = genetic; buccal = inadequate arch space Two main theories have been proposed - Guidance theory (distal aspect of <u>2</u> root) - Genetic theory Authors adopt/adapt current evidence to support their theory	Brin et al., 1986 Jacoby, 1983 Jacobs, 1996 Becker, 1995 Peck et al., 1994
Investigation	<i>If <u>3</u> not palpable buccally at 9-10yrs then investigate</i> - observe - bulge, inclination and colour of adjacent teeth - palpation - of canine crown, mobility of <u>C</u> and <u>2</u> - R/Gs - to establish - Presence - Position - Pathology Clinical signs of palatally impacted <u>3</u> - delayed eruption of <u>3</u> or prolonged retention of the <u>C</u> - absence of normal buccal <u>3</u> bulge or presence of a palatal bulge in the <u>3</u> region - delayed eruption, distal tipping or migration of <u>2</u> - loss of vitality and ↑ mobility of the <u>2</u> or <u>1</u> R/Gs - normally use vertical or horizontal parallax to localise using: 2 x periapicals (at least 20° tube shift needed) - upper anterior occlusal + periapical - upper anterior occlusal + DPT (65-70° tube shift) ↑ the vertical angulation of the X-ray tube from 60-65° to 70-75° to ↑ the effect of parallax - horizontal parallax more accurate among GDPs; 83% of <u>3</u>s were correctly located with horizontal parallax while only 68% with vertical parallax	Mittal et al., 2017 Southall & Gravely, 1987 Southall & Gravely, 1989 Jacobs, 1999a,b Armstrong et al., 2003

	• plain films at right angles • ↑ use of dental cone beam CT (CBCT) to locate • palatal 3's often appear magnified on DPT; 3 nearer to X-ray source and further from film so is magnified • DPT overestimates the angulation and underestimates proximity to midline • 92% palatal canines can be localised with 2 x periapicals	Algerban et al., 2011 Chaushu et al., 1999 Ferguson, 1990 Ericson & Kurol, 1987
Position	Relates to prognosis and complexity of aligning canine • ideally apex in line of arch, crown as upright as possible • horizontal or high position means extended treatment time, so consider alternatives • consider occlusion as a whole	Stivaros & Mandall, 2000
Root resorption of maxillary lateral incisors	• incidence: 12% of cases with impacted 3's, amount underestimated with plain R/G; CT studies show 48% of 2's demonstrate a degree of root resorption; CBCT showed 66% resorption of 2's and 11% of 1's • CBCT can be considered when resorption cannot be ruled out from intra-oral films • risk factors for resorption of lateral roots: - female, age <14yrs, horizontal palatal canines - advanced canine root development - canine crown medial to midline of lateral incisor • the following are not significant risk factors: - size of follicle, angulation of lateral incisor - quantity of primary canine root resorption • resorption of incisor teeth during 3 eruption is most probably a result of: - the contact between the erupting 3 and the incisor - active pressure during eruption - cellular activities in the tissues at the contact points • early R/Gic monitoring of pts with aberrant 3 eruption is needed to detect resorption as early as possible • rarely compromises longevity of 2 • severely resorbed incisors (<10mm) were still stable although ↑ mobility of teeth with ↑ age	Ericson & Kurol, 1987; Ericson & Kurol, 2000; Walker et al., 2005 Algerban et al., 2011 Ericson & Kurol, 1988a Ericson et al., 2002 Becker & Chaushu, 2005 Parker, 1997 Jönsson et al., 2007
Treatment options	No active treatment • review biannually with R/Gs initially and then as necessary; no evidence currently available as to frequency of R/Gic review required in long-term • warnings and monitor for: - root resorption of lateral incisor - cyst formation - transmigration Interceptive treatment • Xtn C/C aged 10-13yrs in uncrowded mouths although doubt on the efficacy of this approach have been stated • more positional change and shorter mean eruption time when C/C Xtn 10-13yrs; 67% improvement in position compared with 42% for control • predictors influence success of 3 normalising, e.g. canine tip, midline/dental arch plane and mesioangular angle • 78% palatal canines show normalization within 1yr (64% in 6mths) in uncrowded mouths • ↑ overlap with 2 ↓ chance of normalising • improvements normally evident in first yr after Xtn • in crowded mouths 62% normalized, further 19% improved indicating crowding adversely effects outcome • evidence suggests ↑ space for 3 ↑ likelihood of eruption: - Xtn C only compared with Xtn C + HG (to ↑ arch length);	Mittal et al., 2018 Hussain et al., 2016 Ericson & Kurol, 1988b Parkin et al., 2018 Bazargani et al., 2014; Naoumova et al., 2015a,b Naoumova et al., 2015b Ericson & Kurol, 1988b Power & Short, 1993 Leonardi et al., 2004

	results showed Xtn only → 50% success (3 erupted) compared with 80% success when Xtn + HG - 3 study groups of palatally displaced 3s: Xtn of C only; Xtn C + HG; untreated control; results showed Xtn only → 65% success (3 erupted), Xtn + HG → 88% success, control → 36% success • make space for <u>3</u> to erupt, consider Xtn of <u>4</u> ± use of URA Exposure and orthodontic alignment • where interception failed or unsuitable • must have space for <u>3</u> to erupt → Xtn <u>4</u> may be needed • wide saucerisation to expose canine and allow to erupt • expose <u>3</u> and bond bracket +/- chain • open or closed exposure can be undertaken; no evidence either method is superior • no difference in aesthetics, cost, periodontal health or pt satisfaction between 2 methods of exposure; orthodontist more likely than lay people to identify previous impacted <u>3</u> • closed exposure found to improved aesthetic result compared with open using Maxillary Canine Aesthetic Index • uncover palatal impacted <u>3</u> early (during mixed dentition) to allow autonomous eruption • surgical exposure and orthodontic traction of <u>3</u> should be performed as early as possible <i>Mechanics</i> • FA/FA approx 2½yrs treatment time • align <u>3</u> with URA (force = 20-60g), URA provides vertical anchorage • 17 x 25 TMA sectional with palatal arch to aid anchorage (force = 75g) Surgical removal • Xtn <u>3</u> and accept <u>C</u>, long-term will need prosthetic replacement • indicated with more malpositioned canines or with limited pt compliance • surgery can further compromise prognosis of <u>C</u> • <u>4</u> as a replacement for <u>3</u>, apply: 1. mesiopalatal rotation 2. buccal root torque 3. grinding the <u>4</u> palatal cusp 4. alternative: to intrude <u>4</u> to improve gingival margin followed by occlusal buildup; suitable for high smile line Transalveolar transplant • where interception has failed and grossly malpositioned <u>3</u> • ideally with open apex at 13-14yrs to aid vitality • danger of ankylosis and submergence means most are done at age 16yrs • optimal development stage for autotransplantation is when the root is 50-75% formed Surgical repositioning • if pt unwilling for complex treatment • apex of canine needs to be in favourable position • ++ alveolar and palatal bone removed and canine swung into place about fixed apex	Baccetti et al., 2008 Olive, 2002 Ferguson, 1990 Usiskin, 1991 Parkin et al., 2017 Parkin et al., 2013, 2015, 2017 Luyten et al., 2020 Kokich, 2004 Becker & Chaushu, 2005 Sagne & Thilander, 1990 Roberts-Harry & Harradine, 1995 Husain et al., 2016 Moss, 1975; Thomas et al., 1998 Kristerson, 1985 McKay, 1978
Factors affecting outcome	• age • viability of permanent canine - ankylosis is a possibility • availability of space • dental health and periodontal status of dentition • motivation and co-operation of pt	Woloshyn et al., 1994

Poor treatment outcome	No treatment • resorption of adjacent teeth • pathological change • poor aesthetics Surgery • damage to adjacent teeth Orthodontic treatment risks • root resorption of <u>2</u> and <u>4</u> adjacent to ectopic canine • pulpal obliteration of <u>2</u>, <u>3</u> and <u>4</u> during treatment may produce a colour mismatch • risk of discontinued treatment because of protracted treatment times • adverse treatment outcome, e.g. canine ankylosed • high labial impactions with apically re-positioned flap tend to reintrude after treatment due to healing process	
Recommended reading	Ericson & Kurol, 1987; Naoumova et al., 2015a,b; Husain et al., 2016; Mittal et al., 2017, 2018; Parkin et al., 2017, 2018	

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Supernumeraries

Definition	A 'tooth' or 'tooth-like' structure which develops in addition to the normal series of 32 teeth	
General features	- incidence: 1-2% 80% occur in anterior Max - M:F = 2:1 - most common cause of failure of eruption of <u>1</u> 10% of midline diastemas due to supernumeraries - rarely occurs in primary dentition (0.8%) - pts with supernumerary primary teeth have 30-50% chance of supernumerary teeth in permanent dentition Associated syndromes - Down's syndrome, cleidocranial dysplasia (gene: RUNX2), CLP anomalies, other rarer syndromes, e.g. Gardner, Ellis-van Creveld	Garvey et al., 1999 Di Biase, 1969 Shah et al., 2008 Brook, 1974 Subasioglu et al., 2015 Shah et al., 2008
Aetiology	- multifactorial - different theories suggested: i. dichotomy of tooth bud ii. hyperactivity of dental lamina iii. genetic influences	Fleming et al., 2010
Clinical signs	- spacing, e.g. midline diastema - failure of adjacent teeth to erupt, particularly associated with failure of <u>1</u> to erupt - eruption into mouth - local crowding or irregularity 10% of diastemas	Yaqoob et al., 2016
Types of supernumerary	Conical - small peg shaped tooth 75% of supernumeraries - roots usually well developed, may erupt or stay deep - may be inverted mesiodens if in midline may lead to median diastema - little effect on incisor eruption - thought to develop as mesial extension of dental lamina - risk of cystic formation/resorption of incisors is very low Tuberculate - barrel shaped tooth 12% of supernumeraries - have no roots and remain unerupted - often in pairs associated with cingulum of <u>1</u>s, i.e. lie palatally, can cause rotations - often delay/prevent eruption of central incisors - thought to develop from a budding of the enamel organ - tuberculate more likely to cause an obstruction than conical (1:5 compared with 1:1) Supplemental teeth 7% of supernumeraries - resemble crown morphology of adjacent tooth - most common in lower incisor or <u>2</u> regions - often found at the end of dental series (2/5/8) - treatment - Xtn of most appropriate one (always check root form radiographically) - most common in primary dentition Odontomes 6% of supernumeraries Complex - disorganised rounded mass of dentine, pulp and enamel; 50% impede eruption of teeth Compound - a mass of discreet denticles each containing dentine, pulp and enamel; 4x more common	Tyrologou et al., 2005 Foster & Taylor, 1969 Katz, 1989

	• 33% of compound odontomes and 50% of complex odontomes prevent eruption of teeth • compounds are 4x more common than complex	
Investigations	1. Clinical 2. R/Gs to localise teeth using parallax (if under 30% calcified will not show on R/G) or CBCT	Southall & Gravely, 1989
Treatment	Depends on type and position of supernumerary, options: i. removal ii. monitoring • tuberculate supernumeraries need to be removed to allow incisor eruption, but only 50% of previously impacted incisors will then erupt spontaneously • Xtn of <u>C</u>s and space maintenance/creation to allow eruption of impacted <u>1</u>; 89% erupt in 9mths; degree of angulation of unerupted <u>1</u> is associated with delay • recommend attaching a bracket at time of supernumerary Xtn or exposure depending on position • conical supernumeraries should only be removed once development of permanent incisors apices is established (>8yrs) • surgical removal of supernumeraries prior to ortho treatment if there is a risk of resorption of permanent roots • may be left if high, but require periodic review • FAs or URA may be used to create space and provide traction to bonded tooth	Chawla & Atack, 2012 Yaqoob et al., 2016 Bryan et al., 2005 Chawla & Atack, 2012
Appliances for treatment	• often need to regain lost space where adjacent teeth have drifted • similar techniques to traction for unerupted canines are used (see section on Impacted Upper Canines) using a bonded bracket, gold chain or cleat allowing attachment to the traction component • may need to Xtn <u>C</u>'s to create space for eruption • URAs can be used where vertical anchorage from the palate is an advantage although they can be cumbersome for clinician and pt to activate • FAs are very often used as they permit simultaneous alignment, space management and OB correction, a significant advantage for pts with more severe dental arch problems	
Recommended reading	Shah et al., 2008; Fleming et al., 2010	

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Unerupted Permanent Incisor

Normal eruption	• 6-7yrs • root formation complete 2-3yrs later	
Delayed eruption	• contralateral tooth erupted > 6mths • <u>1</u>s unerupted and <u>1</u>s erupted > 1yr • deviation from normal eruption sequence	
Incidence	• 0.04% • 2.6% of referred population • M:F = 2.7:1 • ↑ association with inherited dental anomalies, e.g. impacted <u>3</u> on the ipsilateral side with <u>2</u> apices more distally displaced	Grover & Lorton, 1985 DiBiase, 1969 Bartolo et al., 2010 Bartolo et al., 2010 Chaushu et al., 2003
Aetiology	Developmental • presence of supernumerary/odontoma (most common cause of delayed eruption of <u>1</u>, usually tuberculate) • generalised retarded eruption • absence of tooth (rare) • dilaceration (71% developmental, 22% traumatic) Hereditary • CLP • cleidocranial dysplasia • abnormal tooth/tissue ratio • gingival fibromatosis • endocrine abnormalities • bone diseases Environmental • trauma causing dilacerations/malformation/ankylosis • early loss of <u>A</u> (+/- space loss) • impaction • retained primary tooth • cystic formation	Fleming et al., 2008; Mittal et al., 2017 Stewart, 1978
Management	• remove retained primary tooth if no other cause • create and maintain space (82% spontaneously erupt) • remove physical obstruction - remove supernumerary/odontome - 49-91% spontaneously erupt - provide space 78% erupt in 6mths, 89% 9mths - 30-54% impacted incisors will need further surgical intervention to facilitate eruption following supernumerary removal • exposure: closed eruption technique - bond low profile bracket to palatal or incisal to ↓ the risk of gingival fenestration during eruption - consider surgical closed exposure and bonding with gold chain at the time of supernumerary removal to avoid repeat GA * pt < 9yrs - monitor 9-12mths after removal of obstruction before considering exposure or consider exposure if GA required for surgical removal of obstruction * pt > 9yrs - consider exposure - exposure shown to have 90% success • unfavourable root formation - expose and bond - may need RCT and apicectomy - Xtn	Pavoni et al., 2013 Foley, 2004 Bryan et al., 2005 Yaqoob et al., 2016 Chawla & Atack, 2012 Yaqoob et al., 2016 Yaqoob et al., 2016 Yaqoob et al., 2016 Chaushu et al., 2015

	• Xtn - maintain space - prosthesis - allow space closure and re-open prior to definitive restoration - camouflage the 2 as a central incisor • ankylosis - currently no evidence for best management - Xtn and reimplant - Xtn and place implant - decoronation to preserve bone during active growth - prosthetic replacement - osteotomy of dentoalveolar segment • distraction osteogenesis - autotransplantation, e.g. lower 5	Crawford et al., 2008 Kokich & Crabill, 2006 De Souza et al., 2015 Malmgren, 2000 Huck et al., 2007 Czochrowska et al., 2002; Amos et al., 2009
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Transpositions

Definition	• a transposed tooth can be defined as: i) the positional interchange of 2 adjacent teeth, OR ii) the development or eruption of a tooth into a position normally occupied by a non-adjacent tooth • in complete transposition both the crown and root structures are transposed • pseudo-transposition (also known as incomplete transposition) occurs when the crowns of adjacent teeth have changed in positional location but the roots have not (roots remain in the normal tooth order)	Peck, 1998 Ely et al., 2006										
Aetiology	• multifactorial - both genetic and environmental factors • often associated with other dental anomalies, e.g. hypodontia, peg-shaped maxillary lateral incisors • this frequent association with other dental anomalies provides strong argument for genetic basis, however studies have found evidence for local rather than genetic factors being the predominant aetiological component	Peck et al., 1993 Baccetti, 1998 Peck & Peck, 1995; Shapira & Kuftinec, 2001; Ely et al., 2006										
Classification	• three part code: 1. first part: jaw of occurrence 2. second part: transposed tooth 3. third part: site of transposition • jaw and tooth codes:<table><tr><td>Mx : max</td><td>M1 : first molar</td></tr><tr><td>Mn : mand</td><td>M2 : second molar</td></tr><tr><td>P1 : first premolar</td><td>I1 : central incisor</td></tr><tr><td>P2 : second premolar</td><td>I2 : lateral incisor</td></tr><tr><td>C : canine</td><td></td></tr></table> e.g. Mx.C.P1 = transposition of maxillary canine to first premolar position	Mx : max	M1 : first molar	Mn : mand	M2 : second molar	P1 : first premolar	I1 : central incisor	P2 : second premolar	I2 : lateral incisor	C : canine		Favot et. al., 1986
Mx : max	M1 : first molar											
Mn : mand	M2 : second molar											
P1 : first premolar	I1 : central incisor											
P2 : second premolar	I2 : lateral incisor											
C : canine												
Prevalence, incidence and sex distribution	• prevalence: 0.33% • more common in max (76%) • 88% cases are unilateral • more common on left side of arch • most common transpositions in decreasing order of occurrence (commonly involve canine teeth):<table><tr><td>Mx.C.P1</td><td>Incidence: 71%*</td></tr><tr><td>Mx.C.I2</td><td>Incidence: 20%*</td></tr><tr><td>Mx.C.M1**</td><td></td></tr><tr><td>Mx.I2.I1**</td><td></td></tr><tr><td>Mx.C.I1**</td><td></td></tr></table> * more common in females, ** more common in males • most common transposition in mand: C.I2 • Mx.C.P1 and Mx.C.I2 more common in females, rest more common in males • often associated with other dental anomalies	Mx.C.P1	Incidence: 71%*	Mx.C.I2	Incidence: 20%*	Mx.C.M1**		Mx.I2.I1**		Mx.C.I1**		Papadopoulos et al., 2010; Ely et al., 2006 Ely et al., 2006 Plunkett et al., 1998 Peck et al., 1993, Peck & Peck, 1995 Peck et al., 1998 Ely et al., 2006
Mx.C.P1	Incidence: 71%*											
Mx.C.I2	Incidence: 20%*											
Mx.C.M1**												
Mx.I2.I1**												
Mx.C.I1**												
General treatment principles	• must consider the entire malocclusion including extent of crowding, aesthetics, position of root apices, potential resorptive damage and pt motivation • treatment usually takes one of 3 approaches: 1. Xtn of one of transposed teeth and aligned teeth 2. transposed positions accepted and aligned teeth 3. orthodontically move teeth to correct positions	Adam et al., 2020										
Clinical signs of Mx.C.P1 transposition	• 3 lies buccal to the 4 and 5 and is rotated mesiobuccally • 4 is tipped distally and rotated mesiobuccally											
Treatment	• usually accept transposition, correction involves prolonged treatment with low success rate											

	- if premolar roots are distally angulated, interceptive Xtn (C) may allow spontaneous correction - if no crowding then treat non-Xtn - if crowding (rare as transposition usually associated with hypodontia, microdontia) - treat with Xtn of <u>4s</u> <u>3</u> may need bonding before eruption to get it into the line of the arch	
Mx.C.I2 transposition	- pseudotransposition more common than complete transposition - aetiology usually due to trauma in primary dentition and is associated with abnormal incisor root morphology - restorative masking may be necessary	
Clinical signs	<u>3</u> positioned mesiobuccally or mesial to the <u>2</u> <u>3</u> may erupt <u>C</u> usually retained - labially displaced and frequently rotated <u>3</u> and <u>2</u> - diminutive <u>2</u> and missing 5 common - impaction of <u>3</u> or <u>1</u> on side with transposition	Shapira & Kuftinec 2001
Treatment	- Xtn retained primary incisors - usually accept transposition if complete; aim for group function as <u>2</u> poor substitute for <u>3</u> in canine guided occlusion - enameoplasty and addition of composite to <u>3</u> can aid aesthetic result - danger of correction - loose buccal attachment of canine leading to long clinical crown	Shapira & Kuftinec, 1989 Adam et al., 2020
Mx.C.M1 transposition	- rare event, usually associated with early loss of first or second primary molars - accept transposition <u>3</u> erupts in the <u>6</u> space with a mesiopalatal rotation and palatal displacement	
Mx.I2.I1 transposition	- usually due to early life trauma in incisor region - normally accepted, with restorative camouflage treatment	
Mx.C.I1 transposition	aetiology - early loss of central incisor (trauma/caries) with aberrant canine migration	
Mn.I2.C transposition	- frequently pseudotransposed - associated with peg laterals, hypodontia, bilateral occurrence - Xtn of primary teeth, accept transposition, Xtn of lateral if crowding - restorative camouflage - significant association with other dental anomalies cited as evidence for genetic control	Shapira & Kuftinec, 1982, 1983 Peck et al., 1998
Mn.C.I1 transposition	- rare - uncertain aetiology - treatment involves removal of primary tooth, accept transposition, derotation of the transposed 3 and periodontal surgery	Brezniak et al., 1995
Intraosseous migration	- rare - teeth involved: second premolars and canines - intraosseous migration of unerupted teeth more commonly occurs in mand - unusual transmigration of palatally impacted 3 across midpalatal suture (to the other side of maxillary bone) can occur - can cause root resorption of teeth in migration path - usual treatment - surgical Xtn	Peck et al., 1998 Shapira & Kuftinec, 2005 Mittal et al., 2017

Recommended reading	Ely et al., 2006; Adam et al., 2020	
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Double Teeth

Definition	- excessive mesio-distal width of a clinical crown - sometimes called macrodont	
Types	Fusion - union of dentine and/or enamel of two adjacent tooth germs at some stage of development Gemination - attempted separation of a single tooth germ to form 2 separate teeth Concrescence - joining of adjacent teeth via the cementum with obliteration of intervening periodontal ligaments - joins teeth together but without ↑ clinical crown width	Welbury et al., 2012
Aetiology	- unclear - can be associated with syndromes, e.g. facial hyperplasia and medical conditions, e.g. insulin resistant diabetes	Canoglu et al., 2012 Pace et al., 2013
Incidence	0.03-1.9% in permanent dentition - M (1.2%) > F (0.9%) - commonly affects incisors, mandibular premolars and third molars - can occur in primary or permanent dentition - fusion can occur between teeth of the normal series or supernumeraries	Altug-Atac & Erdem, 2007 Pace et al., 2013
Clinical presentation	- if due to fusion ↓ number of teeth present (unless supernumerary involved) - if due to gemination, normal number of teeth present - can be symmetrical - broad crowns with a vertical groove extending toward the gingival sulcus - pulp chamber and root canals may be joined or separated	
Possible problems	- poor aesthetics - crowding - caries along the line of demarcation - periodontal problems - alteration in gingival contour - eruption abnormalities	
Treatment aim	- preserve healthy dentition - restore aesthetics	
Investigations	- plain R/Gs - CBCT to show extent of joining	
Treatment options	- combined planning (joint paediatric dentistry/restorative/orthodontic input) - maintain macrodont +/- restorative modification or interproximal enamel reduction - division of fused teeth if possible, Xtn of one tooth, endodontic treatment may be needed of remaining tooth, orthodontic treatment to close residual space - Xtn of macrodont and space closure or prosthetic replacement - management depends on root and root canal morphology	Pace et al., 2013 Shah et al., 2012 Shah et al., 2012
Recommended reading	Pace et al., 2013	

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Primary Failure of Eruption

Definition	Failure of a permanent tooth to erupt or cessation of initial eruption with no obvious local/systemic causative factor	
Classification	Primary retention - isolated condition associated with localised failure of eruption but no other identifiable local or systemic involvement Secondary retention - unexplained cessation of further eruption of tooth after it has penetrated gingiva • some cases have both types • more recent classification: i) primary failure of eruption (PFE) ii) mechanical failure of eruption (MFE) iii) intermediate failure of eruption (IFE) iv) other	Raghoobar et al., 1991a,b Frazier-Bowers et al., 2007; Sharma et al., 2018
Aetiology	• strong genetic component • associated with syndromes • strong evidence for mutation in parathyroid hormone receptor 1 (PTH1R)	Sharma et al., 2018 Frazier-Bowers et al., 2010
Incidence	• more common in females • more commonly affects molars	Sharma et al., 2018
Features	• usually affects posterior teeth, the bite distal to the first affected tooth is usually open • affected teeth may have initially erupted into occlusion and then cease to erupt or fail to erupt • may be associated with infraoccluded primary teeth, in particular E's • may be unilateral or bilateral • permanent teeth may become ankylosed after failure of eruption has occurred • may have effect on vertical facial growth • diagnosis often made retrospectively	Dunbar & Slaterry, 2015 Proffit & Vig, 1981 Brady, 1990
Treatment options	• depend on presentation • rule out any local/systemic factors • orthodontic extrusion is unsuccessful and tends to intrude the rest of the dentition • consider single tooth or multiple tooth osteotomies once growth is complete or may consider segmental osteotomy • selective Xtns followed by implants • consider restorative options, e.g. crown build-ups	Sharma et al., 2018 Dunbar & Slaterry, 2015 Ireland, 1991 Dunbar & Slaterry, 2015; Sharma et al., 2018 Proffit & Vig, 1981
Recommended reading	Dunbar & Slaterry, 2015; Sharma et al., 2018	

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Ectopic Eruption of Permanent First Molars

Definition	Local eruption disturbance: permanent first molar (6) is blocked from complete eruption by primary second molar (E) which is usually resorbed prematurely on the distal surface	
Classification	Reversible type 6 disimpacts and erupts spontaneously Irreversible type 6 remains impacted against E until treated or when E exfoliates spontaneously	Young, 1957
Incidence	4.3%; range 2-6% 66% of ectopic 6's are reversible - siblings of affected children incidence: 19.8% - max > mand (rare in mand) - M > F - R = L - unilateral: bilateral = 50:50 ↑ 4x higher in cleft than non-cleft children (22%)	Bjerklin, 1994 Kuroi & Bjerklin, 1982a Kennedy, 2008 Bjerklin & Kuroi, 1981 Bjerklin et al., 1993; Bjerklin, 1994
Aetiology	Local Factors ↑ mesial-distal width of 6 ↑ mesial eruption angle of 6 - small max - posterior positioning of max in relations to cranial base - delayed calcification of 6 Genetic Factors - associated with other dental abnormalities, e.g. ectopic canines - familial tendency - associated with clefting	Bjerklin, 1994 Chintakanon & Boonpinon, 1998 Canut & Raga, 1983 Bjerklin et al., 1992; Mooney et al., 2007
Possible effects	Rarely symptomatic but can result in: - pain from pulpitis of E - mobility of E - premature exfoliation of E - caries in 6 - mesial migration of 6 - loss of arch length - impaction of second premolar	Starkey, 1961
Diagnosis	- distal cusps emerge before mesial cusps - unilateral or bilateral delay in emergence of 6 - diagnosis confirmed by dental R/Gs: impaction against distobuccal root of primary tooth and external resorption of E	Heikkinen et al., 2001
Treatment planning	- first determine if ectopic 6 is reversible or irreversible - when reversible 90% self correct by age 7yrs 10% self correct by age 8 or 9yrs - intervention is required if ectopic 6 remains irreversible - treatment planning depends on: - clinical eruption status of 6 - change in position of 6 - amount of enamel ledge of E entrapping 6 - mobility of E - presence of pain or infection If resorption of E < 1.5mm: - observe 3-6mths (to establish if reversible)	Bjerklin & Kuroi, 1981 Kennedy & Turley, 1987

	• if no resorption and vertical position not improved: expose unerupted 6 • if no resorption and vertical position improved: monitor eruption • if still <1.5mm resorption: treatment to move the impacted tooth distally (see below) If resorption of E >1.5mm: • if E symptomatic or mobility >1mm consider Xtn and management of space problem once 6 erupts • if E asymptomatic and mobility <1mm and 6 partially erupted: treatment to move the impacted tooth distally • if E asymptomatic and mobility <1mm and 6 unerupted: expose 6 and commence treatment to move the impacted tooth distally	
Treatment	Treatment to move the impacted tooth distally: • 6 is partially erupted: - brass wire ligature - elastomeric +/- steel spring clip separators - orthodontic band on E with attached distal spring +/- transpalatal arch when maximal anchorage required - orthodontic band on the E and a bonded bracket on the exposed cusp of 6, with an open coil spring • 6 is unerupted: - surgically expose and try above techniques or distal extension attached to SS crown Treatment to distalise mesially erupted 6 following early loss of E: • cervical HG • URA with distalising spring or expansion screw	McDonald & Avery, 1994 Roberts, 1986 Kurol & Bjerklin, 1984 Kennedy & Turley, 1987
Outcome	• 6 erupted or repositioned to normal position • resorption of E is generally stopped once 6 corrects its eruption path • no long-term negative side effects of cervical traction	Kurol & Bjerklin, 1982b Kurol & Bjerklin, 1984
Recommended reading	Bjerklin, 1994; Mooney et al., 2007	

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Molar-Incisor Hypomineralisation (MIH)

Definition	hypomineralisation of systemic origin of 1 to 4 permanent first molars frequently associated with affected incisors	
Aetiology	- ameloblasts affected by systemic disorder at specific stage of development - various causes have been suggested including: - prenatal complications, e.g. maternal illness - perinatal complications, e.g. low birth weight - postnatal complications, e.g. childhood fever, respiratory tract problems - likely that several unknown contributing factors are involved resulting in a number of possible causes	Taylor, 2017 Alaluusua, 2010
Prevalence	3.6-25% (differ between countries and birth cohorts) - global prevalence of 13-14%	Weerheijm, 2004 Rodd et al., 2020
Types of developmental enamel defects	Hypoplastic - quantitative enamel defect - disruption in secretory phase - affected early in tooth development - small pits and grooves Hypomineralised - qualitative enamel defect - disruption in calcification or maturation phase - affected later in tooth development - well demarcated white/brown opacities - normal thickness but quality variable	
Clinical presentation	- soft, porous, brittle - post-eruptive breakdown - enamel defects or white-brown/yellow patches - sharp demarcation between affected and sound enamel - risk of defects to upper incisors ↑ when more first permanent molars have been affected	
Possible problems	- caries - inability to anaesthetise MIH molar - pain and sensitivity - aesthetic of incisors - can be asymptomatic	
Differential diagnosis	- fluorosis (diffuse opacities, caries resistant) versus well demarcated opacities - amelogenesis imperfecta (molars equally affected, appearance of defects more symmetrical in molars and incisors, family history, taurodontism on R/G, affects all teeth)	
Treatment options	- depends on long-term prognosis and specific needs of teeth - temporise with GIC and consider Xtn at ideal time - orthodontic treatment may be needed to close residual spaces - permanently restore with gold onlays if mildly affected - microabrasion - more effective on brown marks	Elhennawy & Schwendicke, 2016 Lygidakis, 2010
Recommended reading	Weerheijm, 2004; Rodd et al., 2020	

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Infraocclusion of Primary Teeth

Definition	Tooth remains in its original occlusal plane whilst rest of arch develops laterally and vertically, making it appear submerged	Kurol, 1981
Incidence	8-14% - follows familial pattern - Ds more commonly affected than Es 10 x more likely seen in the mand due to different curvatures of arches	
Aetiology	- unknown - possible traumatic injury to Hertwig's epithelial root sheath, e.g. chemical or thermal irritation - possible deficiency of bone metabolism - possible disturbance of root resorption	
Clinical presentation	- tooth at inferior occlusal position when compared to adjacent teeth - tipping of adjacent teeth and ↓ in arch length	Tieu et al., 2013
Possible problems	- space loss 'wedging' of primary tooth - difficulty in access for OH, restoration or Xtn - early infraocclusion can result in enforced tooth loss	Hvaring & Bireland, 2019
Classification	Mild - occlusal surface height is less than 2 mm below occlusal height of adjacent teeth Moderate - occlusal surface is at the level of the contact points of adjacent teeth Severe - occlusal height below interproximal contact points of adjacent teeth	Messer & Cline, 1980 
Investigations	- infraoccluded teeth normally ankylosed, confirmed by a high metallic sound on percussion testing - radiographically obliterated lamina dura seen - permanent successor may or may not be present	
Management	Infra-occluded teeth are not amenable to orthodontic movement, options include: monitor - for 6mths if permanent successor present - risk of caries, periodontal disease and ectopic eruption of permanent successor - usually infra-occlusion is temporary and the retained primary tooth will eventually be lost as permanent successor erupts early Xtn - surgical removal may be necessary - if left <i>in situ</i>, can be very difficult to remove requiring excessive alveolar bone removal - consider space maintaining as space loss will subsequently occur complicating future treatment - can ↑ space for Xtn by uprighting adjacent tipped teeth with URA or sectional FA luxation - breaking the bony union between alveolus and teeth then placement of a splint (rarely undertaken) restoration of occlusal height (onlays) - prevents tipping and crowding of adjacent teeth - retains bone in area which may be a site for future transplantation or implant therapy - prevents food packing	Ekim & Hatibovic-Kofman, 2001 Kurol & Thilander, 1984; Tieu et al., 2013 Scott & Atack, 2015, Scott & Atack, 2015 Evans & Briggs, 1996
Recommended reading	Tieu et al., 2013	

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Aids to Diagnosis

How to Assess a Patient

Cephalometrics

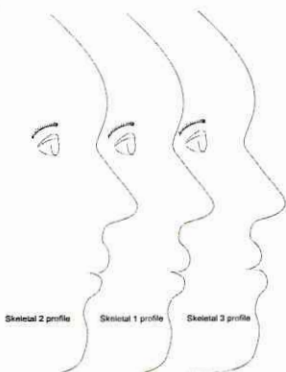
Imaging

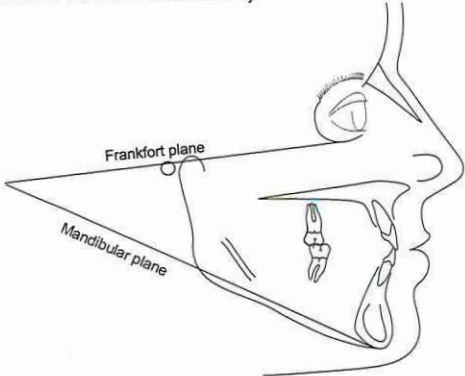
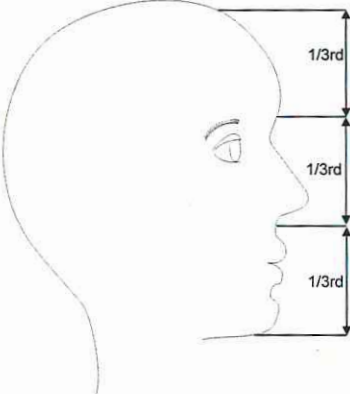
Space Analysis

Indices

When to Refer

How to Assess a Patient

Reason for referral	- what is the reason for referral - treatment or advice? - what are the main features of the pt's malocclusion? - is there a history of previous consultation or treatment? - have you obtained original or high-quality prints of recent relevant R/Gs?	
Pt's presenting concern	- what is the pt seeking, an opinion or active treatment? - what is the pt's main concern? - what are the concerns of the parents/carers?	
Medical history	all orthodontic pts must have a full medical history taken and updates should be checked for at each visit	
Clinical examination	- orthodontic assessment 'crib' sheet can be used (example provided at the end of this chapter) - a basic periodontal examination (BPE) needs to be undertaken especially in adult orthodontic pts	BOS, 2015
Records	- after initial examination collect records to aid diagnosis and plan treatment - types: - SMs (cast or digital) - casts (plaster or plastic) made from alginate impressions or scans of the teeth respectively - R/Gs (see section of Imaging) - Photographs (see section of Imaging) - Kesling set ups: SM can be cut up to show the effects of differing Xtn patterns; process: - teeth cut off plaster SMs and moved to planned position - reattached in new position with wax - useful tool to aid understanding of treatment planning and pt consent	
Extra-oral	- sit the pt upright in the dental chair with the Frankfort plane horizontal parallel with the floor; this is the natural head position - a position in which most pts carry their head which is a relatively constant reproducible position - observations are made both in profile view/laterally and frontally view/anteriorly <i>From the lateral view:</i> - AP: antero-posterior relationship of the max and mand - vertical: facial proportions and Frankfort-mandibular planes angle <i>From the anterior view:</i> - vertical: facial proportions - transverse: asymmetry	Moorrees & Keane, 1958
Lateral view: Antero-posterior (AP)	- the Sk pattern can be (see diagram): - Skeletal 1 - Skeletal 2 - Skeletal 3 	

	- soft tissue profile usually reflects the underlying Sk relationship of max and mand - assessed clinically using Kettle's method - using forefinger and middle fingers to palpate the alveolar bases in reflection of labial sulci of max and mand - A point = deepest concavity of anterior maxilla - B point = deepest concavity of anterior mandible	
Lateral view: Frankfort-mandibular Planes Angle	- the Frankfort plane is a clinical plane which connects the superior notch of the external auditory meatus to the lower border of the orbit - the mandibular plane can be clinically assessed and connects the soft tissue menton to soft tissue gonion (the lower border of the mandible)  - where the two planes meet is the Frankfort-mandibular planes angle with an average value of 28°; if the angle is average then clinically the plane intersect at the occiput - if the angle is ↑: - then the planes intersect in front of the occiput - commonly the lower face height is ↑ - if the angle is ↓: - then the planes intersect in behind the occiput - commonly the lower face height is ↓	
Lateral & Anterior view: Facial Proportions	Craniofacial proportions: - craniofacial proportions are split into thirds (cranium, mid-face, lower face) - the face can be split from the Trichion - Soft tissue Glabella - Subnasale - Soft tissue Menton  Facial proportions: Lower face height - clinically seen from the base of the nose (collumella) to the lowest point on the chin (soft tissue menton) - this should be equal the upper face height (soft tissue glabella to the base of the nose (subnasale))	

	openbite: no vertical overlap between the anterior teeth  Normal Overbite  Increased Overbite  Openbite	
Intra-oral	Comment on: - dental health, e.g. caries and periodontal status Intra-arch - teeth present, e.g. missing teeth? - upper and lower labial segment, e.g. are they normally inclined, proclined, retroclined? - crowding/spacing present? - soft tissue abnormalities, e.g. lip competence, fleshy fraenum or tongue tie Interarch - incisor classification - OJ in mm - OB, e.g. increased, average, reduced or open? - centreline relationship - e.g. centrelines coincident? If not, assess pt from behind and judge whether upper or lower centrelines are to left or right of the facial midline - molar and buccal segment relationships, e.g. Class I, II or III (buccal segment and molar relationships may differ due to missing teeth or crowding and therefore needs to be classified) - any displacements present After an intra-oral assessment - diagnosis summarised - problem list constructed - objectives of treatment listed - treatment planning is usually based around the lower labial segment (LLS), aim to limit proclination/ retroclination as significant alteration of original position → post-treatment relapse potential	
Diagnosis summary	Example - This is {initials} who is 12 yrs of age. She is concerned that her upper teeth stick out. There is no relevant medical history and she has attended with her mum - all teeth are present and erupted, there is no caries, the oral hygiene is excellent - she presents with a Sk CI 2 base and a Class II/1 incisor relationship - the lips are incompetent, but she can achieve an oral seal - the lower labial segment is normally inclined and crowded - the upper labial segment is proclined and spaced - in occlusion the OJ is 12 mm, the OB is increased and complete and the centrelines are co-incident - the upper and lower buccal segments are well aligned and in occlusion the molars are a full unit CI II	
Problem list	This should highlight the problems with the most severe issues at the top of the list Example: - significant Sk CI 2 relationship - increased OJ 12mm - increased OB - LLS crowding - CI II molar and buccal segment relation	

Aims of treatment	This should follow the order of treatment Example: • relieve crowding in both arches • level and align both arches • reduce the OB • reduce the OJ • close residual space and correct the buccal segment relationship to class I • retain the result	
Treatment objectives	• the objectives of treatment are used to outline how you would achieve the aims and what appliances can be used	
Recommended reading	Macdonald & Ireland, 1998	

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Example of Orthodontic New Patient Assessment Form

C/O				Relevant Medical History		Relevant Dental History		History of Dental Trauma			
				Yes ☐	No ☐	Yes ☐	No ☐	Yes ☐	No ☐		
Skeletal Class			FMA		Asymmetry		Lips		Lip Line		
I	☐	Mild ☐	Low	☐	Yes	☐	Competent	☐	High	☐	
II	☐	Mod ☐	Ave	☐	No	☐	Mild Incompetent	☐	Normal	☐	
III	☐	Sev ☐	High	☐			Marked Incompetent	☐	Low	☐	
TMJ		Digit Habit		OH		Teeth Erupted		Caries		BPE	
Yes ☐		Yes ☐		Good ☐							
No ☐		No ☐		Fair ☐							
				Poor ☐							
↓ Incisor Inclination ↑			↓ Incisor Crowding ↑			↓ Buccal Segment Crowding ↑					
☐ Proclined ☐ ☐ Average ☐ ☐ Retroclined ☐			☐ None ☐ ☐ Mild ☐ ☐ Moderate ☐ ☐ Severe ☐ ☐ Spaced ☐			☐ None ☐ ☐ Mild ☐ ☐ Moderate ☐ ☐ Severe ☐ ☐ Spaced ☐					
Incisor Class		Overjet		Overbite		X-Bite		Molar Relationship			
I ☐ II div 1 ☐ II div 2 ☐ III ☐ Bimax ☐				Increased ☐ Average ☐ Decreased ☐ Edge to Edge ☐ AOB ☐ If present, ... mm Complete ☐ Incomplete ☐				R L			
Centre Line				Displacement				R L			
Coincident ☐		Yes ☐ No ☐ Forward ☐ Right ☐ Left ☐		Full I ☐ 1/4 II ☐ 1/2 II ☐ 3/4 II ☐ Full II ☐ 1/4 III ☐ 1/2 III ☐ 3/4 III ☐ Full III ☐		Full I ☐ 1/4 II ☐ 1/2 II ☐ 3/4 II ☐ Full II ☐ 1/4 III ☐ 1/2 III ☐ 3/4 III ☐ Full III ☐					
Radiographs DPT ☐ Ceph ☐ Nasal Occ ☐ Other ☐ Traumatized tooth/teeth ☐											
Report:											
Other Features/ Anomalies/ Problems IOFTN IOTN DHC: AC:											
The IOTN box must be completed.											

Cephalometrics

Definition	- literally - measurement of the head - more commonly - means of using standardised skull R/G to assess facial and dento-Sk relationships																													
History	- developed in 1930's (Broadbent, USA/Hofrath, Germany) - originally postero-anterior and lateral views recommended to allow 3 dimensional assessment - now, as features of greatest importance in sagittal plane, usually refers to use of lateral skull views	Broadbent, 1937																												
Equipment	collimated X-ray source - 5 feet/1.5-1.8m from midsagittal plane of pt to minimise magnification errors cephalostat - head positioner aluminium wedge - ↑ soft tissue definition film - placed 1 foot behind midsagittal plane of pt with rare earth metal intensifying screen - radiation dose/exposure ≈ 6 micro Sv - lat ceph R/G can be reconstructed from large volume CBCT but cannot be justified due to radiation dose	Isaacson et al., 2015 Abdelkarim, 2015																												
Uses	- allows angular and linear measurements to be made - BOS R/G guidelines provide flowcharts to help decide when they are indicated diagnosis and treatment planning - allows assessment of AP and vertical Sk pattern, dental bases, incisor positions and angulations, detection of unerupted teeth and soft tissue profile during active treatment - e.g. end of functional appliance treatment towards end of treatment - must be clinically justifiable during/out of retention - assessment of relapse assessing/monitoring growth - pt's own growth or comparing with "norms" for sex, age and race (use of templates, e.g. Bolton); Bjork structural signs and cervical vertebral maturation can be reviewed (research) - Björk's implant studies - some have expressed doubts over usefulness of cephalometrics for treatment planning purposes in: i. CI I Xtn cases ii. CI II/1 cases	Isaacson et al., 2015 Broadbent, 1937 Björk, 1969 Baccetti et al., 2005 Björk, 1954 Deveraux et al., 2011 Dinçer et al., 2013 Nijkamp et al., 2008																												
Norms	Hard Tissues Common angular values: <table><thead><tr><th></th><th>Caucasian</th><th>Afrocaribbean</th><th>Chinese</th></tr></thead><tbody><tr><td>SNA</td><td>81°</td><td>88°</td><td>84°</td></tr><tr><td>SNB</td><td>78°</td><td>84°</td><td>80°</td></tr><tr><td>ANB</td><td>3°</td><td>4°</td><td>4°</td></tr><tr><td>MMP</td><td>27°</td><td>28°</td><td>28°</td></tr><tr><td>Ui to MxP</td><td>109°</td><td>118°</td><td>113°</td></tr><tr><td>Li to MnP</td><td>93° (120°-MMP)</td><td>101°</td><td>98°</td></tr></tbody></table> Soft Tissues Careful interpretation needed due to errors due to posturing, variable muscle tone and identification of points Common facial reference planes: - Harmony (H) line - should bisect nose - E-line - lower lip should be 2mm and upper lip 4mm behind line - Zero Meridian - vertical line dropped from soft tissue Nasion to soft tissue Pogonion perpendicular to Frankfort plane, vertical reference line to assess A-P position to chin point		Caucasian	Afrocaribbean	Chinese	SNA	81°	88°	84°	SNB	78°	84°	80°	ANB	3°	4°	4°	MMP	27°	28°	28°	Ui to MxP	109°	118°	113°	Li to MnP	93° (120°-MMP)	101°	98°	Riolo et al., 1974; Fonseca & Klein, 1978; Chan, 1972 Holdaway, 1983 Ricketts et al., 1979 Hunt & Rudge, 1984
	Caucasian	Afrocaribbean	Chinese																											
SNA	81°	88°	84°																											
SNB	78°	84°	80°																											
ANB	3°	4°	4°																											
MMP	27°	28°	28°																											
Ui to MxP	109°	118°	113°																											
Li to MnP	93° (120°-MMP)	101°	98°																											

Measurements	• directly or indirectly (tracing) from cephalometric R/G • should also consider: 1. validity - extent to which measurement represents structure under consideration 2. reproducibility - closeness of repeated measurements of the same structure 3. stability of points used to measure • means: 1. via on-screen digitising computer programme 2. scanned by computer 3. by hand • little difference in accuracy of methods Advantages of on-screening digitising 1. time saving 2. 'wild' values more obvious immediately 3. no need to buy expensive and bulky digitising tablets 4. familiar method, uses mouse to digitise directly on screen 5. alter brightness and contrast to make identification of hard and soft tissues easier 6. useful teaching tool in teaching cephalometric digitisation Disadvantages 1. errors involved in recording values and resultant assessment 2. errors may obscure differences between values	Houston, 1983 Houston, 1983 Houston, 1983; Davis & MacKay, 1991 Sandler, 1988; Sandler et al., 2002 Houston, 1983
Types of errors	• Systematic - when a measurement is consistently under/overestimated • Random - variable error with no pattern	Houston, 1983
Specific errors	1. Errors of Projection • arise due to R/G being a 2 dimensional representation of 3 dimensional object • points not in the mid-sagittal plane are distorted according to the <i>laws of perspective</i>: i. angular measurements become too obtuse ii. linear measurements are foreshortened • points on midsagittal plane are unaffected • factors influencing errors: magnification - although standardised set-ups exists, magnification factor of approximately 10% should be taken into account; R/Gic scales are often included to allow this factor to be accurately calculated focal distance of X-ray beam - shorter focal distance → ↑ projection errors longer focal distance → ↓ projection errors head position - should be positioned with Frankfort plane horizontal or in natural postural position, soft tissues relaxed, teeth in centric occlusion (reproducible position) significant errors can occur if positions other than centric occlusion used; careful positioning is recommended, although ± 5° from ideal head position produces errors ↓ 1% • cephalometric analysis based on natural head posture remains valid over time compared with intracranial reference planes to the vertical 2. Errors of Identification Result from many factors: • landmark identification - all points have an 'envelope of error' (e.g. B point easier to identify in AP rather than vertical) which is dependent on:	Baumrind & Frantz, 1971a,b Ahlquist et al., 1986 Solow & Tallgren, 1971 Williamson et al., 1980 Ahlquist et al., 1986 Peng & Cooke, 1999 Baumrind & Frantz, 1971a,b

	i. <i>anatomic characteristics of landmark</i>, points on edges are easier to locate than points within structures as superimposition is less ii. <i>differing definition of landmark</i>, influenced by understanding and experience iii. <i>quality of image</i>, easier point location with clearer images Most reliable point - sella Least reliable points - lower incisor apex; gonion • method of registration - see earlier section • operator reliability - influenced by experience and calibration • cephalometric analysis used - different methods available, some more complicated than others, method chosen should reflect clinical/research use • environment - light box used, ambient light conditions	Stabrun & Danielsen, 1982 Houston et al., 1986 Midtgård et al., 1974 Sandler, 1988 Gravely & Benzies, 1974 Brown, 1981; Houston, 1983
Reducing errors	• careful selection of analysis • clear understanding of point definition • good quality image and standardisation • duplicate measurements • error calculation • care when interpreting results • automated computerised R/Gic identification of landmarks	Houston, 1983; Houston et al., 1986 Rudolph et al., 1998
Super-imposition	Can be undertaken on variety of structures: Natural CRANIAL BASE STABLE STRUCTURES • e.g. Sella-Nasion line (NB: is this really stable as nasion moves with growth?) or DeCoster's line (after age 7 when spheno-ethmoidal synchondroses fuses) • anterior wall sella turcica • greater wings of sphenoid • cribriform plate of ethmoid • orbital roof • inner surface of frontal bone MAX STABLE STRUCTURES • often ANS to PNS with best fit to palatal vault although ANS can remodel • key ridges (zygomatic process of maxilla) • superior and inferior surfaces of posterior hard palate • inferior orbital canal as it exits max MAND STABLE STRUCTURES • anterior chin point • inner border of symphysis • inferior dental canal • any distinct bony trabeculae in symphysis • follicle of 3rd molar prior to root development Artificial • implants (vitalium / tantalum)	Johnston, 1996 Björk & Palling, 1955; Björk, 1969; Björk & Skieller, 1977 Springate, 2015
Cephalometric analyses	Many different types, each have strengths and problems: Those that solely describe jaw disharmony: • Down's - earliest analysis using Frankfort plane as key reference plane; stated importance of using all measurements together rather than each in isolation for pt assessment (based on 20 Caucasians with ideal occlusion) • Harvold • Sassouni - useful for describing face height, Sassouni coined the phrase 'skeletal open bite'	Brown, 1981; Kirchner, 1993 Downs, 1948 Harvold, 1974 Sassouni, 1969

	Those that aid treatment planning: • McNamara - useful in orthognathic planning, 'A' point should be on nasion perpendicular and Pog just behind it • Eastman - most popular in the UK; based on Ballard analysis (250 individuals of various ages) and refined by Mills; 'Eastman correction' can be applied if SNA is high/low and SN/MxP is normal - this corrects for an aberrant position of nasion assuming sella is correct Calculation is: $\frac{\text{measured SNA} - \text{average SNA}}{2} = X$ Then: $\text{measured ANB} \pm X = \text{Eastman corrected ANB}$ X is added where the measured SNA is lower than average and subtracted where measured SNA is higher, e.g. in a case where measured SNA = 88° (normal = 82°) the calculation is: $\frac{88-82}{2} = 3$ - this is then subtracted from the ANB value N.B. Eastman correction was shown to overestimate towards the opposite skeletal discrepancy when N was moved posteriorly towards • Opal - amalgamation of norms derived from other studies • Ballard's conversion tracing - incisor inclinations normalised and OJ measurement taken; an ↑OJ suggests a CI 2 discrepancy • Steiner - now historical (based on 2 Hollywood stars!), used to calculate what dental compensation needed for dental camouflage; uses SN plane as horizontal reference plane • Wits - based on 46 caucasian ideal occlusions, assesses AP jaw discrepancy in relation to each other and not to cranial base; useful if ANB does not reflect clinical findings; influenced by functional occlusal plane and therefore cannot distinguish problems caused by vertical displacement of dentition: Average values: -1mm (male), 0mm (female) Those that analyse change due to growth/treatment • Pancherz - measures linear changes from occlusal line perpendicular (OLp) drawn from sella perpendicular to occlusal plane; can isolate dental and skeletal changes; used in many research papers • Pitchfork analysis - superimposition of 2 or more lat cephs, registered on stable reference points (intersection of cribriform plate and greater wing of sphenoid with line dropped parallel to functional occlusal plane) to demonstrate skeletal and dental change	McNamara, 1983 Ballard, 1956 Mills, 1970 Kamaluddin et al., 2012 Mitchell, 2007 Steiner, 1960 Jacobson, 1975 Pancherz, 1982 Johnston, 1996
Soft tissue prediction	• very variable but maybe possible to predict • 'morphing' images variable in most digitising packages • see section on Orthognathic Treatment	Kneafsey et al., 2008
3D Cephalometric Analysis	• 3D cephalometry has ↑ in recent years, with techniques including CBCT, low-dose multi-slice CT or MRI • particularly helpful for assessing facial asymmetry in comparison to 2D cephalometry, where structures are superimposed on each other • 3D landmark identification = reliability of 2D identification	Periago et al., 2008 Pittayapat et al., 2014
Recommended reading	Baumrind & Frantz, 1971a,b; Houston, 1983; Houston et al., 1986; Isaacson et al., 2015	

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Imaging

Introduction	- defined as artificial imitation or representation of external form of any object - rapid advances in imaging technology in recent yrs - conventional film is a 2D representation of a 3D structure - clinical advances include CBCT and digital models	English Oxford Dictionary
Types of imaging	- clinical photography - R/Gic - optical - video - digital	
2D imaging	common 2D R/Gs - bitewings, periapicals, occlusal, panoramics and cephalometric lateral skull	
Panoramic radiography	- employs principle of tomography or sectional radiology - produces image of a thin slice of tissues within a pt - panoramic image is made by creating a focal trough or region of focus within a generic jaw form and size	Quintero et al., 1999
Tomography	- general term for a technique that provides an image of a layer of tissue 3D images include magnetic resonance imaging (MRI) and computed tomography (CT) - MRI creates an image without using ionizing radiation and is good for imaging soft tissues - CT allows multiple slices to be stacked to give 3D form of hard tissues	
Cone Beam CT (CBCT)	- cone shaped X-ray beam; rotates around pt once to acquire a volumetric data set of region of interest - radiation dosage is considerably ↓ (50-500 μSv) than conventional CT (1200-3300 μSv) but ↑ than conventional R/G - adjunct to 2D imaging to improve pt outcomes - only justified in cases where conventional R/Gs fail to provide a correct diagnosis of pathology - uses in dentistry include localisation of unerupted teeth, cleft lip and palate, perio/endo lesions, TMJ views and implants pre-assessment - CT shows higher sensitivity in assessing presence of root resorption (48%) compared with conventional R/Gs (12%) - sensitivity of CBCT in detecting root resorption: 66.7% - other advantages: < distortion, < superimposition (versus conventional R/G), better at imaging bone and dental hard tissue (versus CT), smaller equipment than CT - disadvantages: high cost, radiation dose, interpretation can be difficult, required to stay still 10-40s - training required to interpret and evaluate images	Merrett et al., 2009 Drage, 2018 De Grauwe et al., 2018 Benington et al., 2010 Ericson & Kurol, 2000 Walker et al., 2005 Drage, 2018
Fixed appliances and CT scans	- FA cause degradation of image quality locally as metallic objects appear black - ceramic brackets do not have same effect - discuss with pt's radiologist/doctor if scan needed as FA/metal bonded retainers may need removing	Dahllof & Huggare, 2004 Beau et al., 2015
Fixed appliances and MRI scans	- effects include: - physical effect - radiofrequency-induced heating - mechanical effects - magnetically induced displacement - artefact formation - significant scatter will occur if scan goes through FA - metallic objects can → star artifacts across image - protocols suggested for pts requiring MRI scans	Shivam et al., 2021 BOS, 2015 Shivam et al., 2021

Stereo-photogrammetry	- data captured using 2 or more cameras and the results combined to form a 3D image - valuable in imaging faces - relatively low cost, fast, safe and easy to operate	Hajeer et al., 2004
Laser scanning	- can be used for 3D facial scanning and digital models - errors can occur where there is void/undercut which the laser is unable to scan - accuracy continues to improve with developing technology	Ireland et al., 2008
Optical surface scanning	- laser scanning has an accuracy of approximately 0.5mm, which is sufficient for detailing the head and face but inadequate for scanning dental casts - optical surface scanning of soft tissues allows the study of face not amenable to cephalometrics - reproducibility needs further assessment	Halazonetis, 2001 Nute & Moss, 2000 Coward et al., 1997
Digital study models	- several different companies available ↑ usage -18% of practitioners in the US - can use plaster model precursor although 3D scanning is ↑ in popularity - minimum quality/data capture for orthodontics 3D scan 200,000 vertices - advantages over conventional models: ↓ storage, ↓ risk of breakage, viewed and shared on-line, diagnostic set ups possible, ease of transfer - digital models offer a high degree of validity when compared to direct measurement on plaster models - area of ↑ research and on-going development	House et al., 2011 Keim et al., 2008 BOS, 2017 BOS, 2017 Martin et al., 2015; BOS, 2015 Fleming et al., 2010 Martin et al., 2015
Digital Cameras	Advantages of digital cameras: 1. speed and immediacy of image capture 2. immediate review and re-exposure of unsatisfactory images 3. data storage and transmission 4. simplified incorporation of images for presentation or documentation 5. absence of film and processing costs 6. no ageing effects of image unlike conventional film	Hutchinson & Williams, 1999 Sandler et al., 2002
Digital Imaging	- this has predominantly replaced 'wet film' processing - perceived benefits of digital over conventional R/Gs: 1. electronic storage and transmission 2. ↓ processing 3. ↓ radiation exposure of up to 30-50% in some systems 4. more environmentally friendly as less processing chemicals and reusable plates - image enhancement is possible to improve diagnostic quality of digital images - image enhancement consists of: contrast improvement, smoothing, edge enhancement - there are 2 types of receptors for direct digital image acquisition: charge-coupled device (CCD) sensor and storage phosphor (SP) image plate - disadvantages of digital imaging: 1. initial outlay of costs to convert from conventional R/Gic systems 2. CCD systems can be bulky and have fibre optic wires 3. cross infection control 4. medicolegal concerns from manipulating images: manufacturers of software programmes have installed 'audit trails' which can track down and recover original images	Forsyth et al., 1996a Brennan, 2002 Forsyth et al., 1996b Isaacson et al., 2015 Brennan, 2002

Recommended reading	Sandler et al., 2002; House et al., 2011; BOS, 2015, 2017; Drage, 2018; IRR, 2017 and IR(ME)R, 2017	
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Space Analysis

Definition	quantification of space required in each arch for the correction of a malocclusion	Proffit et al., 2012
Uses	- assessment of crowding/spacing - Xtn planning - anchorage planning - mechanics planning	
Crowding assessment	- manual or computer aided cast analysis Methods - arch perimeter measured between mesial surfaces of first molars - arch divided into segments 1-3 and 3-6 and straight line approximations made - contour piece of wire to arch and measure - measure mesio-distal tooth widths of each tooth and add widths - use Vernier gauge or dividers - see below for unerupted teeth - numerical difference between arch perimeter and combined tooth widths quantifies crowding or spacing - visual examination - measuring discrepancy (in mm) between space available in the arch between contact points of adjacent teeth and mesio-distal width of displaced tooth - visual examination tends to overestimate degree of crowding and brass wire method tends to underestimate crowding	Schirmer & Wiltshire, 1997 Johal & Battagel 1997
Royal London space planning	- provides formal method of space planning - takes into account: - crowding/spacing - levelling curves of Spee - arch expansion - incisor AP position - angulation of teeth - inclination of teeth - only crowding/spacing, arch width change and incisor AP change can have substantial space implication - others are associated with only small amounts of space	Kirschen et al., 2000a,b
Methods of size estimation for unerupted teeth (Mixed Dentition Space Analysis)	4 types of analysis - R/Gs, measuring the size of erupted teeth - proportionality tables, based on correlating size of various teeth within the arch - equations, which attempt to estimate space required by the permanent teeth - combination of both proportionality tables and R/Gs - measurement using SMs and R/Gs to assess size of unerupted premolars - estimate canine size via proportionality tables using mesio-distal widths of lower incisors - prediction tables: - halve the mesio-distal (M-D) width of $\overline{2}$ to $\overline{2}$ in mm - add 10.5mm for combined width of mandibular canine and premolars in one quadrant - add 11.0mm for combined width of maxillary canine and premolars in one quadrant - combine R/Gs and prediction tables measuring M-D widths of incisors on SMs, and M-D widths of premolars on R/Gs to estimate size of unerupted canines	Carty et al., 2015 Hixon & Oldfather, 1958 Moyers, 1973 Tanaka & Johnston, 1974 Staley & Kerber, 1980

Problems	- arch perimeter difficult to define and measure, depends on chosen line of arch - use of cast photocopies unreliable when using computerised methods due to magnification effects - crowding can manifest as protrusion/retrusion thus affecting arch perimeter - mixed dentition analysis - predictions are for white caucasians only and often underestimate tooth size - amount of space required/gained by different movements varies on an individual basis making accurate space assessment difficult	Champagne, 1992 Proffit et al., 2012 Jaroontham & Godfrey, 2000
Additional factors affecting space requirements	Levelling Curves of Spee (C of S) - measure depth of curve from premolar cusps to flat plane on distal cusps of 6s and incisors - levelling C of S requires space - amount varies depending on depth of OB 1mm space required for 3mm depth of curve, 1.5mm for 4mm depth of curve, 2mm space for 5mm curve - deep C of S of 9mm only requires 2mm of extra space Arch Expansion/Contraction 1mm space provided by 2mm of overall arch expansion; converse for contraction Tooth Angulation - vertical teeth take up ↓ space than correctly angulated teeth - over angulated teeth take up more space - extra 0.5mm space required to correct vertical teeth; applies to 321/123 and lower 3's only Incisor AP change - allow 2mm space to correct each 1mm of OJ - measure OJ with mand in RCP - measure clinically and via lateral cephalometric R/G - AP expansion more effective than lateral expansion in providing space - approx 1mm of arch length gain for 1mm of incisor labial movement Incisor Inclination/Torque 10° change in inclination → 0.5mm space needed - for average shaped incisors, a space requirement of 1mm is expected if all 4 max incisors are torqued by 5° - principle does not apply to the lower incisors because unless they are particularly proclined, the contact points are closer to the incisal edges Molar relationship - molar relationship affected by: i. distal movement of buccal segments, e.g. HG ii. mesial movement of buccal segments, e.g. anchorage loss iii. growth differences in max and mand - difference in total space required for upper and lower arches indicates the molar relationship when incisor AP correction is accounted for - equal space requirement in upper and lower arches when molars are CI I - tooth size differences in upper and lower arches will affect the assessment	Kirschen et al., 2000a,b Braun et al., 1996 Steyn et al., 1996 Noroozi et al., 2002
Tooth size analysis	5% of population are ↑ 2 standard deviations from the mean - tooth size discrepancy - no significant differences in tooth size discrepancy between different malocclusion groups and gender	Proffit et al., 2012 Crosby & Alexander, 1989; Araujo & Souki, 2003

	• upper lateral incisors, and premolars show most variation in size • for good occlusion teeth must be of proportional size • poor interdigitation results if upper and lower teeth are disproportionate • Bolton Analysis used to compare summed mesiodistal widths of maxillary teeth to mandibular teeth, and to compare total widths of all upper and lower teeth (not 7s nor 8s) • Derived formula: Overall ratio = $\frac{\text{sum mandibular '12' x 100}}{\text{sum maxillary '12'}}$ Anterior ratio = $\frac{\text{sum mandibular '6' x 100}}{\text{sum maxillary '6'}}$ • ratios: Overall ratio = 91.3% ± 1.91 Anterior ratio = 77.2% ± 1.65 • if the ratio > mean, indicates mand excess, max deficiency or a combination of both; could consider building up small 2's, tip small 2's to take up more room in the arch, IPR lower arch, or accept disrupted molar relationship/finish with ↓ OJ • these ratios could be one of the tools used in diagnosis (functional and aesthetic outcome) without the use of a diagnostic setup • reference tables used in comparison (time consuming) • computer digitising techniques or scanned images of study casts available - advantage quicker	Bolton, 1958
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General requirement of an Index	• reliable • valid • acceptable to profession and public • require minimal judgement • administratively simple and cheap • sensitivity (identification of indication of need) • specificity (identification of indication of no need)	World Health Organisation, 1977
Types	Occlusal Classification • Angle's classification • Incisor classification Skeletal Classification Malocclusion • Occlusal Index • Handicapping malocclusion assessment record (HMAR) • Index of Treatment Need (IOTN) • Index of Treatment Complexity, Outcome and Need (ICON) • Index of Functional Treatment Need (IOFTN) Treatment Assessment • Little's Irregularity Index • Peer Assessment Rating (PAR) Cleft outcomes • Goslon Yardstick • 5 Year Olds' Index Periodontal • Plaque Index • Gingival Index • Basic Periodontal Examination (BPE) • Mobility Index • Gingival Recession Index	Angle, 1899 Ballard & Wayman, 1964 Houston et al., 1993 Summers, 1971 Salzmann, 1968 Brook & Shaw, 1989; Evans & Shaw, 1987 Daniels & Richmond, 2000 Ireland et al., 2014 Little, 1975 Richmond et al., 1992 Mars et al., 1987 Atack et al., 1997a,b Stilness & Loe, 1964 Loe & Stilness, 1963
Angle's Classification	• assess molar relationships in AP direction: Class I - (neutroclusion) - mesiobuccal cusp of $\underline{6}$ occlude with buccal groove of lower 6 Class II - (distocclusion / post-normal) - mesiobuccal cusp of $\underline{6}$ at least 1 cusp width mesial to CI I division 1 - upper incisors are of average inclination or proclined, OJ is $\uparrow$ division 2 - upper incisors retroclined, OJ is usually minimal but may be $\uparrow$ Class III - (mesioclusion / pre-normal) - mesiobuccal cusp of $\underline{6}$ at least 1 cusp width distal to CI I • nowadays $\frac{1}{4}$ and $\frac{1}{2}$ unit CI II / III are also used	Angle, 1899
Incisor Classification	• based on relationship between the lower central incisor edges and the upper central incisor's cingulum plateau: Class I - lower edges occlude with or lie immediately below cingulum plateau Class II - lower edges lie posterior to cingulum plateau division 1 - OJ is $\uparrow$ and the upper central incisors are normally inclined or proclined division 2 - upper central incisors are retroclined, OJ is usually minimal but may be $\uparrow$ Class III - lower edges lie anterior to cingulum plateau, OJ is $\downarrow$ or reversed • often inter-examiner disagreement over the classification	Ballard & Wayman, 1964; British Standards Institution, 1983 Williams & Stephens, 1992

Skeletal Classification	usually a clinical assessment, often supported by lateral cephalometric R/Gic investigation: Class 1 - lower dental base is normally related to the upper, ANB is 2-4° Class 2 - lower dental base is retruded relative to the upper, ANB > 4° Class 3 - lower dental base is protruded relative to the upper, ANB < 2°	Houston et al., 1993												
Occlusal Index (OI) (Historical interest - rarely used now)	- reasonable reproducibility and validity - scores: i. dental age ii. molar relationships iii. OB and OJ iv. posterior crossbites and open bites v. tooth displacements vi. centrelines vii. missing upper 2 - complicated scoring system - more reliable method of ranking severity than HMAR	Summers, 1971												
Index of Treatment Need (IOTN)	- based on the index of treatment priority used by the Swedish Dental Board - attempts to rank malocclusion - clinical tool, used to assess eligibility for NHS treatment 2 aspects: Dental Health Component (DHC) - grouped in 1 of 5 categories: 1 (no need for treatment) → 5 (very great need for treatment) - most severe trait scored - ruler used - assessed in order: i. Missing teeth ii. Overjet iii. Crossbites iv. Displacements (contact point) v. Overbite - reliable over time - limitations have been recognised Aesthetic Component (AC) - ranking system (1-10) using colour photographs - assesses dental attractiveness: 1 (most attractive) → 10 (least attractive) - operator score improves over time - not utilised by GDPs - associated with OHQoL - has been criticised due to subjectivity and lack of representation of CI III, CI II/2 and AOB	Linder-Aronson, 1974 Brook & Shaw, 1989 Cooper et al., 2000 Ferguson, 2006 Evans & Shaw, 1987 Cooper et al., 2000 Ho-A-Yun et al., 2009 Liu et al., 2011												
Index of Treatment Complexity, Outcome and Need (ICON)	- aims to assess treatment inputs and outcomes - based on international orthodontic opinion from 97 orthodontists - occlusal traits are weighted and the summary score used to assess need for treatment 5 occlusal traits identified:<table><tr><td></td><td>weighting</td></tr><tr><td>1. IOTN Aesthetic Component</td><td>7</td></tr><tr><td>2. crossbite</td><td>5</td></tr><tr><td>3. upper arch crowding/spacing</td><td>5</td></tr><tr><td>4. buccal segment AP relationship</td><td>3</td></tr><tr><td>5. anterior vertical relationship</td><td>4</td></tr></table> - pre-treatment SMs are scored assessing treatment need - assessing post-treatment SMs indicates treatment outcome		weighting	1. IOTN Aesthetic Component	7	2. crossbite	5	3. upper arch crowding/spacing	5	4. buccal segment AP relationship	3	5. anterior vertical relationship	4	Daniels & Richmond, 2000; Firestone et al., 2002
	weighting													
1. IOTN Aesthetic Component	7													
2. crossbite	5													
3. upper arch crowding/spacing	5													
4. buccal segment AP relationship	3													
5. anterior vertical relationship	4													

	5 'grades' of complexity identified: ICON Score Range 1. Easy < 29 2. Mild 29-50 3. Moderate 51-63 4. Difficult 64-77 5. Very Difficult > 77 - any summary score > 43 would be considered for treatment - to assess the degree of improvement the post-treatment score is multiplied by 4 and the result subtracted from the pre-treatment score 5 'grades' of improvement identified: Improvement Grade ICON Score Range 1. Greatly > -1 2. Substantially -25 to -1 3. Moderately -53 to -26 4. Minimally -85 to -54 5. Not improved / worse < -85 - Index tries to enable assessment of treatment need and outcomes - one limitation is that it is heavily weighted by aesthetics - does not account for poor compliance - shown to have high validity - PAR and ICON have high level of agreement in terms of treatment outcome - ICON and DHC of IOTN have good levels of agreement - recommended level of acceptable inter-rater agreement is ± 18 points	Fox et al., 2002 Fox et al., 2002 Borzabadi-Farahani & Borzabadi-Farahani, 2011 Brown & Richmond, 2005
Index of Orthognathic Functional Treatment Need (IOFTN)	- based on IOTN but developed to better categorise the functional need for orthognathic treatment 5 point scale similar to the DHC of the IOTN - intra-rater reliability was moderate to good and inter-rater reliability was good to very good	Ireland et al., 2014 James et al., 2015
Little's Irregularity Index	- assesses irregularity of lower labial segment - measures contact point displacement in mm, mesial to lower 3's - summed displacement of adjacent anatomical contact points of mandibular teeth - used in assessment of stability and relapse >3.5mm deemed unacceptable	Little, 1975 Ormiston et al., 2005 Little et al., 1981
Peer Assessment Rating (PAR)	- assigns scores to different occlusal traits using SMs - accumulative score - pre and post-treatment total scores are compared using PAR nomogram → assesses improvement - is not an index of treatment need, clinical judgement is required when applying - all dental staff can be trained to use - can be insensitive and misjudge individual pt needs 5 components, each have individual weighting: weighting UK US i. upper and lower anterior segments 1 1 ii. left and right buccal segments 1 2 iii. OJ 6 5 iv. OB 2 3 v. centrelines 4 4	Richmond et al., 1992 Gorray et al., 1999 Burden & Strafford, 1996 DeGuzman et al., 1995

	- change expressed as: i. <i>reduction in weighed PAR score</i>: 22 point reduction → greatly improved ii. <i>% reduction in weighed PAR score</i>: <30% reduction → worse/no better ≥30% reduction → improved - indicator of clinical performance, suggested aim: 75% of cases to score 70% ↓ or better with 3% or fewer cases having a ↓ lower than 30% - highly correlated with orthodontists' subjective assessment of treatment need - recommended level of acceptable inter-rater agreement is ± 12 points - valid and reliable in UK and US - early debonds have lower PAR reduction - limitations of PAR 1) generic weighting of OJ and OB - weightings should be derived for each malocclusion; these have been suggested 2) sensitive to malocclusions with high OJ 3) OB low weighting 4) zero weighting for displacements	McMullan et al., 2003 Hamdan & Rock, 1999 Brown & Richmond, 2005 DeGuzman et al., 1995; Firestone et al., 2002 McMullan et al., 2005 Hamdan & Rock, 1999
Goslon Yardstick	- assesses outcome in unilateral CLP pts - measures dental arch relationships and quality of facial growth 10yr olds' records - SM index - ranking system which assesses surgical outcome - Group 1 → excellent outcome - Group 5 → very poor outcome	Mars et al., 1987
5 Year Olds' Index	- assesses outcome in unilateral CLP pts 5yr olds' records - SM index - ranking system which assesses surgical outcome - Group 1 → excellent outcome - Group 5 → very poor outcome	Atack et al., 1997a,b
Tooth Wear Index	- assesses pathological tooth wear - all surfaces examined - subjectively scored from 0 (no wear) to 4 (loss of enamel or pulpal exposure)	Smith & Knight, 1984
Plaque Index	- records levels of supragingival plaque present - does not indicate plaque control - does not record subgingival area - subjective scoring: 0 - no plaque at gingival margin 1 - initial deposit of plaque at gingival margin (not visible to the eye) 2 - plaque at gingival margin (visible to the eye) 3 - heavy accumulation on tooth	Stilness & Löe, 1964
Gingival Index	- assess and records gingival condition - subjective scoring: 0 - healthy 1 - mild inflammation, slight change in colour 2 - moderate inflammation, redness, moderate glazing, bleeding on pressure 3 - severe inflammation, redness, hyperplasia, tendency for spontaneous bleeding	Löe & Stilness, 1963

	• Patient Reported Experience Measures (PREMs) provide information about the actual process of receiving treatment • PROMs and PREMs have been increasingly used in orthodontics alongside traditional clinician based outcome assessments • Oral Health Related Quality of Life (OHRQoL) measures represent the pt's subjective assessment of the extent to which their oral health impacts on their well being and enjoyment of life • global measures attempt to capture overall OHRQoL by asking a single question while multi-item measures ask a number of specific conceptually related questions which reflect on different dimensions of OHRQoL; these often include physical, functional, psychological and social factors • orthodontic related PROMs may be generic such as Oral health Impact Profile (OHIP), Child Perception Questionnaire (CPQ) or condition specific Orthognathic Quality of Life Questionnaire (OQIQ), Psychosocial Impact of Dental Aesthetics Questionnaire (PIDAQ), Malocclusion Impact Questionnaire (MIQ)	Sischo & Broder, 2011 Thomson et al., 2012 Zhang et al., 2006 Cunningham et al., 2002 Patel et al., 2015
Recommended reading	Järvinen, 2001	

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When to Refer

Consideration for referral	• must know the expected developmental milestones for a pt of any age • role of the GDP is to 'spot the unusual' and refer appropriately • there are questions to help with referral decision: i. are all the teeth healthy? ii. is the patient in the primary, mixed or permanent dentition? iii. is the correct number of teeth present? If not, why not? iv. is the eruption pattern symmetrical and correct for the child's 'dental age'? v. are the teeth well aligned and in a satisfactory occlusion?	
How to make a referral	• provision of orthodontic care varies across the UK (specialist practice, community dental settings or hospitals) • orthodontic providers have guidelines for referral and some many also have proformas on which referrals are made • if no guidelines are available for referral then a good referral letter includes the following information: i. pt demographics ii. reason for referral, i.e. treatment or advice iii. salient features of the pts' malocclusion iv. history of previous treatment v. original or high quality prints of recent R/Gs where relevant	Jawad et al., 2015 Ashley et al., 2020
Primary dentition	Indication for considering referral: • severe skeletal discrepancies/craniofacial anomalies • severely delayed dental development • missing/supplemental teeth • history of head and neck radiotherapy +/- chemotherapy • advice for balancing/compensating Xtns	Scott & Atack, 2015
Mixed dentition	Indication for considering referral: • severe skeletal patterns where early treatment may be appropriate, e.g. developing Sk CI 2/3 • dental anomalies, e.g. double teeth, dens-in-dente • developmentally absent permanent teeth • supernumerary teeth • teeth in unfavourable positions, e.g. canines • impacted first permanent molars • infraoccluded teeth • crossbites • Xtn advice where severe crowding evident or first molars have poor prognosis • advice following trauma to permanent teeth	Scott & Atack, 2015
Permanent dentition	Indication for considering referral: • IOTN - eligible for NHS treatment? (see section on Indices) - YES - refer to NHS Orthodontic provider - NO - consider refer for private assessment after discussion with pt • remember, every pt has the right to a second opinion • adults may qualify for NHS treatment if they require multidisciplinary care, e.g. orthognathic surgery	Scott & Atack, 2015

Recommended reading	Scott & Attack, 2015	
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Interceptive Orthodontics (IO)

Interceptive Orthodontics (IO)

Timing of Interceptive Orthodontic Treatment

Permanent First Molars of Poor Prognosis

Early Loss of Primary Teeth

Early Treatment of Crossbites

Loss of Permanent Incisor

Interceptive Orthodontics (IO)

Definition	Any treatment procedure which, eliminates or reduces the severity of a developing malocclusion as this may reduce the need for further treatment or make this simpler	Chung & Kerr, 1987
Need	- developing problems in the primary or mixed dentition could be fully corrected with relatively simple interceptive treatment in 15% of cases and improved in 49% of cases 1 in 3 community pts assessed as in need of IO but only 20% underwent recommended procedure - GDPs' lack of self-confidence is ↑ barrier to providing interceptive orthodontic care - lack of evidence that early treatment carries additional benefit but does not imply early treatment is ineffective	Ackerman & Proffit, 1980 Al Nimri & Richardson, 2000 Borrie et al., 2015 Sunnak et al., 2015
Main aims	- minimise extent of developing malocclusion by: i. maintain midline ii. prevent development of full unit CI II molars iii. minimise crowding - prevention of trauma - psychosocial factors	Batista et al., 2018
Normal occlusal development	- mixed dentition phase starts from age 5-6yrs to exfoliation of the last primary tooth (see section on Chronology of Tooth Development) - typically the 1st molars erupt into ½ unit II molar relationship guided by the distal surfaces of the 2nd primary molars (flush terminal plane) - transition to Class I molars occurs as a result of: i. early mesial drift of lower 6 into primate space ii. late mesial drift of lower 6 into Leeway space iii. differential mand growth - Leeway space: - in max = 1.5mm on each side - in mand = 2-2.5mm on each side - upper permanent incisors erupt into a wider arc and more proclined than the primary incisors; length ↑ up to 13yrs in max and 8yrs in mand - upper canines develop palatally, but migrate buccally to lie distal to the root apex of the lateral incisors - mand inter-canine with established by age 8 yrs	Fleming et al., 2008a Moyers, 1988 Bishara et al., 1998 Bishara et al., 1997
Routine 'screening'	- by GDPs from 8-10yrs old, monitoring developing dentition and looking for abnormalities - clinical exam - 'recognise the unusual' - R/Gs <i>only if clinically justified</i>, commonly DPT and naso-occlusal 30% of DPTs demonstrate orthodontically significant findings - always apply A.L.A.R.P. principle (as low as reasonably practicable) to radiography	Scott & Atack, 2015 Isaacson et al., 2015 Neal & Bowden, 1988
Possible problems in the developing dentition	Premature loss of primary teeth - possible localisation of pre-existing crowding - centreline shift - depends on which tooth, timing and amount of pre-existing crowding (see section on Early Loss of Primary Teeth) - may need to consider space maintenance Retained primary teeth - a difference of more than 6mths between the loss of the contralateral tooth should be regarded with suspicion - may need R/G investigation - can also cause deflection of permanent tooth	Borrie & Bearn, 2013

	Infraocclusion (see section on Infraocclusion) - where the permanent successor is present, infraocclusion usually temporary and should be kept under observation Ectopic eruption of first permanent molars (see section on Ectopic Eruption of First Permanent Molars) Impacted permanent canines (See section on Impacted Upper Canines) Poor quality first permanent molars (see section on Permanent First Molars of Poor Prognosis) Supernumerary teeth (see section on Supernumeraries) Abnormalities in tooth form (see section on Double Teeth) - can affect space requirements and subsequent spacing or crowding Dilacerations - can cause failure of eruption, midline shifts, difference in alveolar bone height - where mild may be able to expose and apply traction - where severe may require Xtn and space maintenance	Scott & Atack, 2015 Pace et al., 2013 Topouzelis et al., 2010; Walia et al., 2016
Timing	See section on Timing of Interceptive Orthodontic Treatment	
Premature tooth loss - Indications for space maintenance	- central incisor loss to maintain space and aesthetics - primary molar - if spaced arch/neglected mouth/mild-moderate crowding present which probably will need orthodontic Xtn's later → no - otherwise in intact arch with just enough space or with severe crowding needing >1 unit space → yes Means - fixed - band/crown + loop/TPA/lingual arch - removable - where multiple teeth missing Complications - fracture, failure of band cement or solder joints - pain, caries, soft tissue overgrowth - interference with eruption of permanent teeth - pt co-operation - adjustment or new appliances may be necessary with continued development and changes in the dentition	Crawford et al., 2008 Watt et al., 2018
Recommended reading	Fleming et al., 2008a,b; BOS Publication: Managing the Developing Dentition, 2010; Scott & Atack, 2015	

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Timing of Interceptive Orthodontic Treatment

Treatment timing	- to eliminate impediments to normal development hence allowing 'ideal' dental development - number of different factors influence timing Depends on: - proposed interceptive measures - pt's dental and Sk maturity - most conditions suitable for IO are present by 10yrs Late mixed dentition offers best window for IO: - E space still present - approx 80% still treatable non-Xtn - treatment can be one phase - growth can still be utilised - some evidence that appropriate early treatment may ↓ the need for specialist orthodontic treatment later - weight of evidence points to reserving early treatment for localized problems and specific situations	DiBiase, 2002 Pietilä et al., 2008 Björk, 1972 Al Nimri & Richardson, 1997 Kerosuo et al., 2008 Fleming, 2017
Indications for interceptive treatment	- correction of Class 2 skeletal discrepancy - correction of Class 3 skeletal discrepancy - Xtn of primary canines (See section on Impacted Upper Canines) - Xtn of poor prognosis 6's (see section on First Molars of Poor Prognosis) - dissuade aberrant habits - correction of anterior/posterior crossbites with associated displacements (see section on Early Treatment of Crossbites) - primary tooth Xtns (see section on Early Loss of Primary Teeth) - space maintenance - psychosocial benefit	Borrie & Bearn, 2013 O'Brien et al., 2003b
Not indicated	- dental health benefit in crowding - no evidence that crowding in mixed dentition affects periodontal health in the long-term - limited evidence to suggest that changing breathing or eating habits can affect the Sk and dental relationships	Bollen et al., 2008 Mew, 2004
Correction of Class 2 skeletal discrepancy	- concept of 2 phase treatment: <i>in mixed dentition</i> - growth modification with early use of functional appliances (starts 1-3yrs before full peak adolescent growth spurt) <i>in permanent dentition</i> - following period of retention a 2nd phase of treatment involving relief of dental crowding and alignment of teeth (females need to be treated earlier than males to maximise growth potential) - advocates of early treatment feel that this will maximise chances of growth modification - evidence suggests that early treatment is no more effective than orthodontic treatment in early adolescence but can ↓ the risk of incisor trauma	Batista et al., 2018
Randomised controlled trial	Preadolescents with > 7mm OJ, in 3 groups: - Control (observation only); 2) HG; 3) Functional appliance 30% of group 1 had favourable growth - groups 2 and 3 had significant average reduction in ANB - group 2 > maxillary restraint - group 3 > ↑ in mandibular length Following fixed appliance treatment: - only small differences in AP relationships between groups	Tulloch et al., 1998; Tulloch et al., 2004

	- during fixed phase the advantage gained by early treatment was lost - changes in occlusion were similar - more permanent Xtns in group 3 than in 1 or 2 - surgery considered least often in group 3 cases - fixed phase shorter in groups 2 and 3 but overall treatment time longer than in group 1	
UK based multicentre trial	- comparison of early treatment (average 9.7yrs) with treatment started later (average 12yrs) - pts treated with TB appliance - early treatment provided no advantage in terms of Sk pattern or significant ↓ in Xtn pattern - those that had early treatment had: i. more attendances ii. received treatment for longer iii. had poorer final dental outcome	O'Brien et al., 2003a,b O'Brien et al., 2009
Disadvantages of early treatment	- co-operation has time expiry - approximately 3yrs - choice of Xtn is difficult whilst young - early start and late finish therefore prolonged course of treatment - soft tissues do not mature until 12-14yrs - with vertical growth of lips - affects stability of corrected OJ ↑ in arch length not maintained in permanent dentition	Berg, 1979 Livieratos & Johnston, 1995 Vig & Cohen, 1979 Little et al., 1990
Advantages of early treatment	- favourable changes in AP relationship achieved but may not be clinically significant ↓ risk of trauma to incisors (45% 10yr olds with OJ more than 9mm have traumatised incisors) - OJ >3 mm are approximately 2x risk of injury to anterior teeth than OJ <3 mm; risk ↑ with ↑ OJ - RCT comparing early versus late treatment concluded: - all groups experienced trauma - very early treatment may prevent trauma but not cost effective - eliminate growth/local disturbances before they have had time to act fully - better co-operation - pts < 12.3yrs: x3 more likely to complete functional treatment - craniofacial tissues more malleable - elimination of gingival/palatal trauma - improved prognosis for adolescent treatment - psychosocial advantages if pt is treated early ↑ self-concept scores	O'Brien et al., 2003a Batista et al., 2018; Todd & Dodd, 1985 Nguyen et al., 1999 Koroluk et al., 2003 O'Brien et al., 2003a Banks et al., 2004 Shaw et al., 1980; O'Brien et al., 2003b
Correction of Class 3 skeletal discrepancy	- face-mask therapy - thought to be most successful when performed in the early mixed dentition - early correction (pt under 10yrs) with protraction HG investigated in a multicentre RCT - in facemask group (FMG) SNA was protracted on average 1.4° compared to 0.3° in control group (CG) - in FMG SNB moved backwards 0.7° - overall difference in ANB between FMG and CG was 2.6° - treatment was successful in 70% of pts - self concept improvement after treatment was not evident - follow-up results demonstrated results maintained although not significantly better than control - there may be short-term benefit compared to no treatment however in the long-term this is not significant - may ↓ need for orthognathic surgery	Franchi et al., 2004 Mandall et al., 2010 Mandall et al., 2012 Mandall et al., 2012 Watkinson et al., 2013 Mandall et al., 2016

Digit sucking habit	- digit sucking is common in the mixed dentition; seen in 12% of 9yr old and 2% of 12yr olds - effects related to frequency, intensity and duration of habit - persistent digit-sucking >6hrs is associated with a significant malocclusion <i>Management - evidence of success equivocal</i> - child must want to stop - conservative methods first - positive reinforcement, use of bitter flavoured nail varnish, finger bandage and use of glove - if habit persists - consider use of orthodontic appliances such as removable appliances, functional appliance or fixed palatal arch but heavily dependent on compliance	Brenchley, 1991 Borrie et al., 2015
Correction of crossbite with displacement	Anterior crossbites - can lead to significant incisal wear and periodontal damage with loss of attachment in the lower incisor region - aesthetic concerns and continued forward mandibular displacement - aim to treat as soon as possible - correction may be achieved with removable appliances with Z/T springs and posterior capping or fixed (2 x 4 appliance) - URA compared with FA for anterior crossbite correction - both effective but shorter treatment time (1.4mths) with FA, stability similar in both - stability of the corrected result depends on achieving a positive overbite (self-retentive) - check position of unerupted 3's as proclination of 2 may move root against erupting 3 Posterior crossbites - may be corrected to prevent them from becoming established in the permanent dentition - occlusal wear, periodontal problems and facial asymmetry can occur if left untreated - correction with a URA with a midline expansion screw or quad; quad may be more successful than URA; both of these approaches are known to produce dental rather than skeletal change	Borrie & Bearn, 2011 Fleming, 2017 Wiedel & Bondermark, 2015a,b Agostino et al., 2014 Petrén & Bondemark, 2008
Space maintenance	- maintain space and aesthetics for loss of a central incisor as soon as possible - consider maintaining space following early loss of 2nd primary molar and subsequent crowding - if spaced arch/neglected mouth/mild-moderate crowding present which probably will need orthodontic Xtn's later → no - otherwise in intact arch with just enough space or with severe crowding needing > 1 unit space → yes - types include: primary tooth (ideal), band and loop, lingual/palatal arch, URA	Crawford et al., 2008
Conclusions	- treatment during primary dentition is inappropriate - treatment during mixed dentition is reserved for: <i>elimination of local factors</i> e.g. supernumeraries, habits <i>direct trauma to soft tissues</i> <i>severe trauma to soft tissues</i> <i>space maintenance if necessary</i> <i>crossbites with displacement</i> - anterior and posterior	Borrie & Bearn, 2013 Ninou & Stephens, 1994
Recommended reading	DiBiase, 2002	

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Permanent First Molars of Poor Prognosis

Incidence	12% of Xtn cases referred to secondary care involve first permanent molars	Bradbury, 1985
Clinical indications	Consider Xtn of first permanent molars when: - extensively carious 6 - most common reason (70%) - hypoplastic first molars - linked with molar-incisor hypomineralisation (MIH) (see section on MIH) - heavily filled first molars where premolars are healthy - apical pathology or root treated first molars - molar crowding and reasonably positioned 8s - high MMPA - AOB cases	Albadri et al., 2007 Weerheijm, 2004 Aras, 2002
Potential problems	Lower arch - space closure can be difficult - lower 2nd molar tends to tip mesially and roll lingually (exaggerated by CI II elastics) - MBT prescription helps limit this with ↓ lingual crown torque (-10°) - use full size archwire for active space closure (19x25SS) - keep space closing forces gentle - treatment time depends on achieving good second molar to second premolar contact (usually 6-9mths longer than equivalent 4s Xtn case) - Xtn of lower 6 can result in overeruption of upper 6 → locked occlusion - unerupted lower 5 can become impacted against 7 - if follicle of lower 5 appears distally tipped, consider taking lower E as well as lower 6 Upper arch - rapid upper first molar space closure (distal angulation of upper 7 follicle) - upper 7's have conical root → less suitable for anchorage - if all first molar space is needed, significant anchorage reinforcement is required, e.g. HG, TADs - only offers a few mms of space if anchorage not supported, e.g. by TPA + Nance button, HG, TADs - tendency for upper 7 to rotate around palatal root Other problems - space often in wrong place for orthodontic needs - may have to wait for 7's to erupt before starting treatment 'necking' of alveolus (dense cortical bone) can make space closure difficult → poor contacts/stagnation areas - space closure can → small buccal and lingual dehiscences in lower 7 region - sometimes difficult to achieve root parallelism - if space present between lower 7 follicle and 6 then unfavourable for space closure	Santos et al., 2017
Timing of Xtns	Early Xtn and management of crowding later - indication: pt in pain or non-cooperative - advantage: less restorative intervention, delay treatment until more cooperative - disadvantage: may need further Xtns later, e.g. premolars Delay Xtns to act as space maintainer to utilise space later - temporise if correction of malocclusion requires space - indication: cooperative pt, crowding or ↑OJ present - advantage: space from compromised tooth used to treat malocclusion	Cobourne et al., 2014

	- disadvantage: temporising restorative work needed, space management more difficult - if space needed, delay Xtn of 6s until 7s have erupted and allow TPA + Nance button or URA to be placed Timely Xtns for spontaneous space closure - indication: mild crowding, CI I malocclusion, all teeth present including 8's - advantage: allows spontaneous space closure - disadvantage: 8's may not be visible until 14yrs	
Timing of Xtns for spontaneous space closure (interceptive Xtns)	Upper first molar - if 7 unerupted rapid space loss is seen - timing less critical than lower Xtn as rapid mesial movement of 7 due to distal angulation of follicle 92% spontaneous space closure Lower first molar 8-10yrs but dental age of pt more important - Xtn timing critical, maximum spontaneous space closure likely when bifurcation of 7 visible on R/G - maximum spontaneous space closure when Xtn of first molar once 1/3 root length and bifurcation of 7 formed 66% spontaneous space closure - if Xtn too early → no radiographic evidence of 8's developing at this stage, 5's can drift distally, labial segments can retrocline and ↑ OB, especially in uncrowded lower arch, e.g. CI III cases - Xtn too late → mesial tipping of 7's → poor contact point and residual spacing - if all space needed, allow eruption of 7s and fit lingual arch to 7's before Xtn - good space closure with late Xtns in lower arch can still be achieved if: 7's are distally tipped, moderate crowding in premolar region - Xtn of other 6's depends on their <i>quality</i>, the <i>occlusion</i> and <i>presence of other teeth</i> - improved prognosis for space closure with 5 situated between roots of E, presence of 3rd molars and mesial angulation of 7's - presence/absence of 8s and 7s angulation were clinically significant factors for space closure	Gill et al., 2001 Teo et al., 2013 Sandler et al., 2000 Teo et al., 2013 Teo et al., 2016 Patel et al., 2017
Advantage of Xtn of first molar	- removes tooth of poor prognosis ↑ chance of 8's erupting successfully - development and emergence of 8s may be accelerated	Williams & Hosila, 1976 Yavuz et al., 2006
Balancing Xtn	- removal of second tooth in the same arch but on the opposite side, to preserve midline and molar symmetry - rarely done for 6's	
Compensating Xtn	- removal of a tooth on the same side of the mouth but in the opposing arch, to preserve molar relationship and ↓ the risk of overeruption - commonly done for Xtn of lower 6 but not for upper as upper more likely to overerupt	Ashby & Noar, 2018
Treatment planning for the loss of first permanent molars	Consider the need for compensating ± balancing in each individual case, but general comments: Class I malocclusion <i>Carious upper 6's</i> - no crowding or minimal crowding - aim for Xtn at optimal time for spontaneous space closure - severe crowding - either delay Xtn until 2nd molars have erupted OR Xtn at optimal time and treat crowding later when permanent dentition is established	Cobourne et al., 2014

	<i>Carious lower 6's</i> - plan case according to amount of crowding - leave contra-lateral lower 6's if sound Class II malocclusion <i>Carious upper 6's</i> - Xtn the upper 6's at optimal time and sagittal correction with a functional appliance - Xtn upper 6's at optimal time then treat with premolar Xtns later; 3rd molars should be present ideally - Xtn upper 6's following eruption of 2nd molars and use space for OJ ↓; careful anchorage management required <i>Carious lower 6's</i> - plan case according to amount of crowding Class III cases: <i>Unilateral carious upper 6:</i> - maintain 6/6 whilst correcting anterior crossbite <i>Unilateral carious lower 6:</i> - preserve contra-lateral if possible - space closure can be difficult - mand keeps growing Ideal interceptive case for Xtn of all 6's - CI I - mild/moderate crowding - no rotations - all successional teeth present and 3rd molars present - lower 2nd molar bifurcation beginning to form, angle between long axis of crypts of 6 and 7 = 15-30° and crypt of lower 7 overlaps the root of lower 6 Ideal late case for Xtn of 6's - crowding in premolar region possibly due to early loss of primary teeth - distal tip to 2nd molar	
Xtn Advice	- guidelines recommend review prior to Xtn 6's by orthodontist - email triage model for assessment ↓ need for joint planning clinics	Cobourne et al., 2014 Tahir et al., 2019
Recommended reading	Cobourne et al., 2014	

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Early Loss of Primary Teeth

Primary teeth	- normal space maintainers, particularly C,D and E - early loss tends to re-distribute crowding, however loss of E can result in rapid upper space loss	
Limiting the detrimental effects of early loss	Balancing Xtn - Removal of second tooth in same arch but on the opposite side, to preserve midline and molar symmetry (not necessarily same tooth in opposing/other side of arch) Compensating Xtn - Removal of a tooth on same side of the mouth but in the opposing arch, to preserve molar relationship (not necessarily same tooth in opposing/other side of arch) Space maintenance Classically indicated when: - just enough space for all permanent successors to erupt - when further space loss will result in more than 1 unit of space to correct malocclusion - difficult to assess clinically	Royal College of Surgeons Guideline, 2006 Crawford et al., 2008
Premature tooth loss	Incisor (A, B) - minimal effect on midline - usually no interceptive treatment needed Canine (C) - consider balancing Xtn to preserve midline symmetry, especially in crowded arch First primary molar (D) - spaced arch - no balancing/compensating Xtn needed - mild crowding - consider balancing Xtn - if in maxillary arch consider compensating Xtn to prevent CI II buccal segments from developing - if in mandibular arch consider compensating Xtn if prognosis of tooth or tooth quality is poor - if pt expected to need orthodontic treatment in future then interceptive Xtn depends on degree of crowding, midline and tooth quality Second primary molar (E) - minimal effect on midline but may → crowding, 6's come forward quickly, particularly in the upper - no need for balancing Xtn but consider compensating Xtn to stop CI II buccal segments from developing	Royal College of Surgeons Guidelines, 2006 Avramaki & Stephens, 1988
Potential problems	- problems depend on: - tooth lost - ↑ space loss in max than mand - age of pt at loss - ↑ space loss in younger pt - amount of crowding present - ↑ rate and amount space loss in crowded arches - unilateral loss of teeth, but opposite side intact acting as control: - loss of D → space for incisors but shift in centreline - loss of E → space loss due to mesial drift of buccal segments - as a result of primary loss ↑ need for orthodontic treatment - orthodontic need is significantly associated with number of primary teeth Xtn; each primary tooth Xtn prematurely led to 18%↑ in orthodontic need in permanent dentition - relative arch spacing has the greatest influence on the outcome of early loss, especially if E is lost - space can be regained during the later mixed dentition phase	Martins-Júnior et al., 2016 Bhujel et al., 2014 Lundström, 1955 Wright & Kennedy, 1978

	- vacuum-formed or banded fixed space maintainers were clinically effective in maintaining space after early loss of primary second molar - current research (PLATOON) reviewing premature loss of baby teeth and its impact on orthodontic treatment need	Barros et al., 2021 Brown et al., 2019
Serial Xtns (historical interest)	- classical form now outdated: - removal of Cs at age 8-9yrs approximately - removal Ds 1yr later - removal of 4s once they erupt - indications: - crowded incisors at 8-9yrs - arch relationship CI I - OB normal - all permanent teeth normally positioned 6's good prognosis 4's ahead of 3's in eruption - series not undertaken often now although the removal of Cs is undertaken in selective cases: - provide space for crowded unerupted upper incisors or incisors in lingual crossbite - provide space for severely crowded lower incisors - RCT demonstrated questionable benefit in the interceptive Xtn of lower C's to relieve LLS crowding in 8-9yr olds - crowding ↓ in Xtn and non-Xtn cases but more in Xtn cases, however arch length shortened in Xtn group suggesting mesial migration of molars; also lower incisors can significantly retroclined - provide space for incisor which have been delayed by supernumeraries - to encourage alignment of palatally positioned 3's however this treatment has been questioned	Kjellgren, 1948 Graber, 1971 Stephens, 1989 Killingback & Stephens, 1989 Kau et al., 2004 Sayin & Turkkahraman, 2006 Ericson & Kurol, 1988, Naoumova et al., 2015, Parkin et al., 2018
Recommended reading	Royal College of Surgeons Guideline, 2006	

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Early Treatment of Crossbites

Posterior Crossbite		
Definition	buccal cusps of the lower teeth occlude buccally to the buccal cusps of the upper teeth	
General features	- affects 8-22% of population - not usually self correcting - may be dental or skeletal in origin - if skeletal may be transverse or AP disharmony between max and mand - interference of primary canine can cause mandibular shift - aim of treatment → to stop crossbite becoming established in the permanent dentition - early treatment → development of normal occlusion - early treatment of unilateral crossbite with displacement may obviate the need for FA in permanent dentition	Petrén et al., 2003 AAPD, 2019
Treatment	- expand and eliminate displacements - different treatment modalities suggested: - URA - midline expansion screw and posterior capping - Quadhelix - RME (not recommended in primary dentition) - evidence suggests quadhelix most successful in correcting posterior crossbite - Haas screw expansion showed 6s to have ↑ buccal and distal inclination after treatment, opposite to controls; ↑ in buccal inclination was ↑ on crossbite side - retain upper E's if possible to maintain space - grind ± expansion (more in mixed dentition) - correction by slow max expansion in mixed dentition is stable in 84% at age 13yrs - following treatment with URA or RME, 34% 6s erupted into crossbite, type of treatment not a significant predictor	Bell & Lecompte, 1981; Petrén et al., 2003; Petrén & Bondemark, 2008 Agostino et al., 2014 Bukhari et al., 2018 Thilander et al., 1984 Petrén et al., 2003 Huynh et al., 2009 Masucci et al., 2017
Anterior Crossbite		
Definition	occurs when 1 or more ULS teeth occlude palatal to incisal edges of the LLS - may result in mandibular displacement	
Aetiology	- local causes - crowding, retained primary tooth - skeletal - CI 3 base - trauma - repositioned, subluxed tooth - developmental - problem with primary palate formation, e.g. in CLP	
General features	- upper incisors tend to erupt lingually and are trapped especially in crowded cases - limits lateral excursions and early treatment is indicated - need to assess if there is enough space to accommodate tooth/teeth to be moved - often need to remove Cs to correct laterals 10% of population - can cause: - enamel wear/occlusal trauma/periodontal problems - mandibular displacement - displacement of tooth out of line of arch - unfavourable aesthetics - TMD (evidence is weak see section on TMD)	
Treatment	Push teeth over bite with URA - Z-springs or anterior expansion plate (screw) - posterior capping - stability of result depends on good OB	Borrie & Bearn, 2011

	• +/- Xtn of Cs (to maintain centreline) and space maintainer also needed to provide space • no significant differences (OJ & IC widths) observed between use of a URA with finger springs and bite plane versus bonding of RMGIC bite pads on lower 6s • correction with a lower RA has been reported Treatment with FA • 2 x 4 appliance - <u>21/12</u> bonded, <u>6/6</u> banded, continuous archwire • biteplane maybe necessary • stability of result depends on good OB • URA and FA both effective and stable after 2yrs but treatment duration 1.4mths shorter with FA • before proclining 2 confirm unerupted 3's position as proclination of 2 may move its root against 3 follicle and result in resorption - possible reason to delay treatment of crossbite	Miamoto et al., 2018 Borrie & Bearn, 2019 McKeown & Sandler, 2001 Wiedel & Bondemark, 2015a,b
Recommended reading	Agostino et al., 2014	

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Loss of Permanent Incisor

Aetiology	- usually upper central incisor lost through trauma - single permanent maxillary incisor - holoprosencephaly	DiBiase & Cobourne, 2008
Treatment options	Depends on: - degree of crowding/spacing - attitude of pt/parent - time elapsed since loss of the incisor - presenting malocclusion (other missing teeth) - oral hygiene - availability of potential donor tooth for transplant	Jawad et al., 2019
Space maintenance	- space maintainer fitted as soon as possible after loss of incisor to prevent space loss and potential centreline shift - URA with prosthetic tooth and wire cleats to hold space open if prosthetic tooth lost - will prevent tipping into space and preserve centreline - may need to maintain space until full orthodontic needs are established - maintains aesthetics	Crawford et al., 2008
Basic options	- move lateral into space and restore, problems with symmetry and aesthetics - plan to conserve space, may involve Xtn of another tooth in the same quadrant, if space closure has occurred - can consider allowing space closure to preserve bone and open space later - may require bone graft where bone loss - restore with partial denture, bridge, implant or autotransplantation	Czochrowska et al., 2003 Kokich & Crabill, 2006 Dietschi & Schatz, 1997; Amos et al., 2009
Considerations for opening or closing space	- Sk relationship, CI 3 → open, CI 2 → close - spacing/crowding - colour, form and gingival margin of adjacent teeth - occlusal features, e.g. buccal occlusion, OJ - pt's co-operation and wishes 'Diagnostic' set-up is useful to assess possibilities and to aid discussion with pt	
Options for replacement of missing tooth if opening space	- careful management needed during FA treatment to maintain aesthetics - removable appliance with prosthetic tooth - adhesive bridge - osseointegrated implant once growth ceased - autotransplantation - can be carried out immediately post avulsion - do not delay to avoid alveolar bone loss - consider if due to loose teeth for relief of crowding - ideal donor tooth: - lower first premolar (shape/size/single root) - upper second premolar (but reduce palatal cusp) - transplant when root is 2/3-3/4 formed (to allow continued root development) - good long-term results quoted (79-100%) - 81% survival rate at 6yrs, 4.8% ankyloses, 19% root resorption - stage of root development is the most important factor in determining pulp healing (ideal= ¾ - 4/5 complete)	Sharma, 2013 Bowden & Harrison, 1994; Barber et al., 2020 Monteiro et al., 2019 Kvint et al., 2010 Tanaka et al., 2008; Kvint et al., 2010 Machado et al., 2016; Nazzari et al., 2019 Andreason et al., 1990

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Treatment

Anchorage
Extraction versus Non-Extraction
Extractions and Facial Profile
Extraction of Specific Teeth
Removable Appliances
Fixed Appliances
Headgear (HG)
Reverse (Protraction) Headgear
Alternative Methods for Anchorage Support and Molar Distalisation
Temporary Anchorage Devices (TADs)
Functional Appliances
Aligners
Arch Lengthening (Anteroposterior Expansion) and Lateral Expansion
Correction of Skeletal Maxillary Transverse Arch Deficiency
Adult Orthodontics
Orthognathic Surgery
Distraction Osteogenesis

Anchorage

Definition	Resistance to reactionary forces during treatment in all 3 planes, i.e. resisting the forces resulting from Newton's 3 rd Law, namely: every force has an equal but opposite reactionary force	
Principles	- rate of tooth movement is related to force per unit root surface area - differential force theory - teeth with ↑ root area have ↑ resistance to tooth movement and, therefore, ↑ anchorage value - not a linear relationship between surface area and tooth movement, therefore other factors involved - large individual variation in rate of tooth movement for a particular force applied - tooth movement ↑ with ↑ applied force but only to a point - optimal level exists after which if you ↑ the force there is no ↑ in tooth movement only ↑ strain on anchor units ↑ number of teeth in anchor unit to ↑ surface area ↑ anchorage value by restricting anchor teeth to bodily movement - do not use heavy forces - can view anchorage in terms of space management: maximise wanted tooth movement minimise unwanted tooth movement - always consider in 3 spatial planes: AP, lateral, vertical - occlusal interferences can effect anchorage	Hixon et al., 1970 Pilon et al., 1996 Dudic et al., 2013 Quinn & Yoshikawa, 1985 Naish et al., 2015 Dudic et al., 2013
Classification	- minimum < 30% of Xtn space needed - moderate 30-60% of Xtn space needed - maximum > 60% of Xtn spce needed	
Sources/types	Intraoral Teeth <i>simple</i> - 1 tooth against another <i>compound</i> - more than 1 tooth in anchor unit - intramaxillary - same arch - intermaxillary - opposing arches (CI II/III, X-elastics) <i>reciprocal</i> - equal force applied to equivalent teeth which → equal movement towards each other <i>stationary</i> - tipping versus bodily movement, e.g. in Begg technique Soft tissue/Bone <i>soft tissue</i> - lip musculature utilised with lip bumper <i>bone</i> - palatal vault utilised in removable appliance design and Nance button <i>cortical</i> - cortical plates provide ↑ resistance to tooth movement than cancellous bone; mandibular teeth have ↑ anchorage value than maxillary teeth <i>implants (permanent/TADs)</i> - have been used clinically for reinforcement of anchorage or for traction - evidence equivocal as to whether surgical anchorage is more effective than conventional anchorage Extraoral <i>HG</i> - anchorage from cranial vault/basal bones - protraction, e.g. hypodontia cases - extra-oral anchorage (EOA), <i>rule of thumb</i>: if more than ½ Xtn space (4mm) required to align teeth and achieve CI I canine relationship then EOA will be required - multi centred RCT compared effectiveness of TADs vs Nance vs HG; no significant differences in effectiveness, pts preference should be taken into account	Quinn & Yoshikawa, 1985 Hixon et al., 1969 Ricketts et al., 1979 Hixon et al., 1970 Ismail & Johal, 2002; Young et al., 2007 Jambi et al., 2014; Sandler et al., 2014 Sandler et al., 2014

Anchorage creation	• distal movement of upper buccal segments with EOT +/- 'Nudger' appliance • implants and distalisation • fixed molar correctors, e.g. pendulum appliance, tend to procline upper incisors • lip bumper to distalise lower molars, tends to procline LLS • Xtn pattern/functional appliances - do not create anchorage but alter the anchorage balance	Cetlin & Ten Hoeve, 1983 Ismail & Johal, 2002 Patel et al., 2009 Cetlin & Ten Hoeve, 1983
Supplementing anchorage	• bond/band 7s • extra-oral anchorage • Xtn decision - no difference in anchorage loss comparing Xtn upper 4s versus upper 5s • lingual arch/palatal arch ± Nance button, evidence contradictory: - lingual arch maintained space in lower arch at expense of LLS proclination, did not prevent 6's moving mesial - palatal arch - no vertical or A-P anchorage effects - palatal arch - actually caused more anchorage loss - no clinical significance between palatal arch and palatal arch + nance, pts preferred palatal arch - no difference in anchorage loss for TPA versus no anchorage supplementation • HG, Nance and HG equally effective clinically but pts preferred TAD • intermaxillary elastics • fixed CI II traction, e.g. saif spring, jasper jumper • functional appliances • toe-in (1st order) and tip-back (2nd order) bends • ankylosed teeth • implants - standard restorative - miniscrew/TAD (direct or indirect anchorage) - mid-palatal • miniplates • onplants • bracket slot size no influence on maxillary molar anchorage loss	Naish et al., 2015 Rebellato et al., 1997 Zablocki et al., 2008 Radkowski, 2007 Stivaros et al., 2009 Diar-Bakirly et al., 2017 Sandler et al., 2014 Kokich et al., 1985 Odman et al., 1995 Young et al., 2007 Naish et al., 2015 Block & Hoffman, 1995 Yassir et al., 2019
Reducing anchorage strains	• ↓ stress on periodontal ligament of anchor teeth • tip teeth • light forces • ↓ friction, e.g. self-ligating brackets • separate retraction of canines • push rather than pull canines • correct centrelines one tooth at a time • avoid round tripping	Quinn & Yoshikawa, 1985
Assessment of anchorage need	Tooth movements required • space required to complete alignment, i.e. 'how much can anchor units be allowed to move?' • bodily/tipping • angulation of teeth - ↑ anchorage required mesial < upright < distal • inclination of teeth - ↑ anchorage required proclined < retroclined Friction (see section on Friction) • unknown amount • produces resistance to tooth movement hence ↑ anchorage demands • dependent on many factors	Naish et al., 2015 Tidy, 1989

Forces required to move teeth	MOVEMENT	FORCES (g)	
	• tipping • bodily • extrusion • intrusion • root uprighting • rotation	35-60 70-120 35-60 10-20 50-100 35-60	
Recommended reading	Quinn & Yoshikawa, 1985; Ismail & Johal, 2002; Jambati et al., 2014; Naish et al., 2015		

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Extraction versus Non-Extraction

Definition	Extraction - reduction in the total number of dental units	
History 1910's	Over the yrs there has been much debate on this subject Angle - believed everyone had the capacity to have 32 teeth in functional occlusion - believed 32 teeth would provide the best aesthetics for each individual, therefore believed in expansion - philosophy was consistent with Wolff's law that bone would form in response to stress (functional loading) Case - strongly criticised Angle's non-Xtn dogma because of its effect on facial aesthetics, i.e. excess dental protrusion following extreme expansion - Case was generally ignored	Bernstein, 1992 Angle, 1907 Case, 1964
1940's	Tweed - disappointed with relapse - hence retreated 100 cases with Xtn of 4 first premolars, observed that the occlusion was much more stable - took cases by train around the USA to show groups - managed to convince others that Xtn were necessary Begg - independently of Tweed, Begg abandoned a non-Xtn policy due to concerns about relapse rather than profile - believed that lack of attrition in modern diet could be compensated by Xtn	Begg, 1954
1960's	- Xtn debate has reopened - Begg and Tweed philosophies unsubstantiated - Seattle Seafair princess showed that public prefer a fuller profile - concern about litigation along with other factors has brought about a marked ↓ in Xtn in the USA 40 yr review of Xtn frequency: - 30% had Xtn in 1953 - 76% had Xtn in 1968 - 28% had Xtn in 1993 - 15% had Xtn in 2014 Reason for decline in Xtns since 1968: - concern - facial aesthetics - TMD - Xtn does not guarantee stability - litigation - change in techniques - use of FA - Begg technique used declined - Straight Wire and EOA - bonds rather than bands - self-ligation	Riedel, 1957 O'Connor, 1993 Proffit, 1994 Keim et al., 2014
Why extract teeth?	- relief of crowding (without excessive expansion) - OJ and OB reduction - anchorage considerations - buccal segment relationship correction - incisor relationship in CI III cases/lower incisor retroclination to correct CI III relationship	
Proposed disadvantages of Xtns	- mand dysfunction - little evidence to support this (see section on TMD) - less attractive facial appearance (see section on Xtns and Facial Profile)	Beattie et al., 1994

	- potentially longer, more difficult treatment - pain, anxiety and other possible adverse effects of the actual Xtn procedure	
Factors in Xtn decision (see section on Space Analysis)	- before planning the Xtn of any permanent teeth must ensure that all remaining teeth are present, sound and developing in a satisfactory position - medical history - tooth quality - large caries/restoration, severe root resorption, hypoplastic, severe dilaceration - pathology - amount of crowding: 0-4mm mild >4-9mm moderate >9mm severe - site of crowding, i.e. posterior/anterior, e.g. 4mm incisor crowding more anchorage demanding than 2mm premolar crowding each side - impacted teeth - missing teeth - occlusal features: - OJ - OB - flattening a curve of Spee will require space - buccal segment relationship - centreline discrepancies - anchorage considerations - Sk considerations: - sagittal jaw relationships - the more severe the crowding the less space is available for camouflage - vertical dimension - low angle cases less likely to extract as thought that space closure can be more difficult, however space closure affected more by gender and active growth but not FMPA - transverse dimension - elimination of crossbites by expansion creates space - profile and soft tissue - ease of Xtn - future treatment considerations, e.g. orthognathic planning and avoiding Xtn in lower arch - long-term stability	Proffit et al., 2012 Rinchuse et al., 2015, Jerrold et al., 2019a, Jerrold et al., 2019b Björk, 1969 Möller, 1966 Ireland et al., 2016 Ackerman & Proffit, 1997
Recommended reading	Jerrold et al., 2019a,b	

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Extractions and Facial Profile

Determinants of soft tissue contours of the face	- Sk foundation - dental support - soft tissue components of nose, chin, lip tone and thickness	Ackerman & Proffit, 1997
Soft tissue profile changes with age	- similar direction and magnitude changes in male and female - greatest change: 10-15yrs in females 15-25yrs in males - angle of soft tissue convexity changes little age 5-45yrs - upper and lower lips more retruded in relation to aesthetic line ages 15-45yrs	Bishara et al., 1998
Preferred profiles	- straight male/convex female profile preferred - least attractive face: where ANB>5° ↑ vertical dimension less attractive in females - as AP and vertical diverged from normal attractiveness ↓ - most attractive profile: - CI I with normal FMP - male - CI I with ↓ FMP - female - least attractive profile male and female: - CI II with ↑ FMP - lip protrusion acceptable if big nose or big chin	Czarnecki et al., 1993 Knight & Keith, 2005 Knight & Keith, 2005 Abu Arqoub & Al-Khateeb, 2011 Abu Arqoub & Al-Khateeb, 2011 Abu Arqoub & Al-Khateeb, 2011
Effect on hard tissues - incisor retraction	- slight effect on incisor retraction reported ↓ incisor retraction the more posterior the Xtn site	Williams & Hosila, 1976
Effect on soft tissues	- highly variable and far less predictable effect - wide variation in AP changes of lower incisor position with premolar Xtn - position of the lips and soft tissue APo varies greatly despite achieving hard tissue APo goals - computer modifications of pt photos demonstrates that lay people are less concerned about profile changes than orthodontists - most likely changes associated with incisor retraction include lip retraction, interlabial gap closure, ↑ of nasolabial angle - initial lip protrusion can help with decision making in borderline cases	Shearn & Woods, 2000 Park & Burstone, 1986 Spyropoulos & Halazonetis, 2001 Hodgkinson et al., 2019 Iared et al., 2017
Xtn changes facial profile	160 subjects had 4x4 Xtns: - mean ↑ in naso-labial angle = 5.2° - mean lip retraction measured to E line = 3.5mm - examined long-term effects of non-Xtn and Xtn treatment → Xtns had flatter profile to begin with therefore had more retraction during treatment BUT non-Xtn group had flatter profiles long-term due to their inherent soft tissue pattern - compared borderline Xtn-non-Xtn cases → Xtn cases did have slightly flatter profiles than non-Xtn cases but were no less pleased with the result - in Xtn and non-Xtn treated CI II/1 cases: - upper and lower lips more retrusive in Xtn groups, and protrusive in non-Xtn groups - Sk and soft tissue profiles straighter with Xtns - average soft tissue and Sk measurements close to but on opposite side to averages from Iowa Growth Study norms	Drobosky & Smith, 1989 Luppanapornlarp & Johnston, 1993 Paquette et al., 1992 Bishara et al., 1997

	iv. Xtn and non-Xtn have no detrimental effect on profile if Xtn decision based on sound criteria • effect of Xtn treatment, a function of initial lip protrusion - Xtn potentially beneficial when lips protrude > 2-3mm behind Ricketts' E-line • upper and lower lips retracted and nasolabial angle ↑ following premolar Xtn: - upper lip retraction ranged from 2mm to 3.2mm - lower lip retraction ranged from 1mm to 4.5mm • 20yr follow up of Xtn/non-Xtn CI I cases: - Xtns lead to average of 2mm ↑ retraction of lower lip to E line - ↑ of 5° of nasolabial angle in the Xtn group compared to no change in non-Xtn group - this has minimal effect on aesthetics of profile	Bowman & Johnston, 2000 Leonardia et al., 2010 Konstantonis, 2012
Xtn does not change facial profile	• comparing 4's and 7's - ↑ retraction of incisors with 4's Xtn group, however no significant group differences in upper lip protrusion or angle of facial convexity • assessment by lay people of profile changes: - profiles of Xtn cases better perceived than non-Xtn immediately post treatment - all groups perceived more favourable post treatment - overall, no significant difference in perception of Xtn and non-Xtn facial profiles • no significant difference in full face or facial profile between pts having 4 premolar Xtns and non-Xtn treatment • lip position more retrusive in non-Xtn cases • no significant effect of Xtn on soft tissue profile as assessed by laser scanning • treatment of CI II/1 cases with or without Xtns did not influence long-term facial attractiveness • systematic review: no significant difference in aesthetic outcomes between premolar Xtn and non-Xtn groups • 25yrs recall - Xtn treatment versus no treatment controls: - Xtn treatment no deleterious impact on facial profile - different directional changes for soft tissue of Xtn treatment group vs untreated controls	Staggers, 1990 Bishara & Jakobsen, 1997 Boley et al., 1998 James, 1998 Ismail & Moss, 2002 Janson et al., 2016 Iared et al., 2017 Rathod et al., 2015
Effect on buccal corridor	• Xtn treatment did not result in narrower max dental arches, whereas non-Xtn treatment slightly expanded dental arch • Xtns and smile width - studies have looked at whether or not Xtns cause a 'dark buccal corridor' and found this is not the case	Akyalcin et al., 2011 Johnson & Smith, 1995; Gianelly, 2003a,b
Conclusion	• premolar Xtns seem to have small effect on profile but not necessarily detrimental • growth and soft tissues are the overriding factors • soft tissue changes do not follow 1:1 ratio • evaluation of profile is largely subjective • growth of chin and nose influences profile in long-term • Xtn treatment did not result in narrower max dental arches • lip precumbency improves following Xtn of 4 premolars, this improvement is predictable; small changes and do not dramatically modify profile • individual variation in response is large • inappropriate Xtn will ↓ lips support • inappropriate non-Xtn will result in excessive lip fullness	Paquette et al., 1992 Park & Burstone, 1986 Paquette et al., 1992 Akyalcin et al., 2011 Leonardia et al., 2010 Leonardia et al., 2010

	• factors other than Xtn pattern will also influence final profile, e.g. pretreatment lip thickness, initial malocclusion and mechanics used • debate will doubtless continue!	Wholley & Woods, 2004 DiBaise & Sandler, 2001
Recommended reading	Paquette et al., 1992; Luppapornlarp & Johnston, 1993; Ackerman & Proffit, 1997; DiBaise & Sandler, 2001	

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Extraction of Specific Teeth

Lower incisor	Indications for Xtns - traumatised, heavily restored or non-vital lower incisor - periodontally involved tooth - distally tipped canines - distally fanned lower incisors - excessive size of lower incisor teeth or small $\underline{2}$ - ectopic eruption of lower lateral incisor - single lower incisor excluded from the arch and remaining incisors well aligned - crowding of 5mm (equivalent to a lower incisor) localised in lower labial segment with buccal segments well intercusped - CI III cases where the upper is well aligned and want to narrow the lower intercanine width and retrocline lower incisors to improve the incisor relationship - adult presenting with full unit CI II in the buccal segment and 5mm crowding in the lower arch (Xtn of 2 premolars in the lower arch may be extremely challenging) - long term stability more favourable than with premolar Xtn - can be effective option in selected cases, e.g. CI II malocclusions with 2 upper premolar Xtns - mild-moderate Class III, edge-to-edge anterior occlusion, anterior crossbite, mild anterior mandibular tooth size excess, minimal open bite tendencies Contraindications for Xtn - deep OB $\uparrow$ OJ - poor buccal segment relationship - mesially angulated canines - poor prognosis of posterior teeth - mild (<3mm) or severe (>7mm) lower incisor crowding Problems associated with lower incisor Xtn - treatment will normally involve FAs $\downarrow$ of lower intercanine width resulting in $\uparrow$ OB and OJ - loss of interdental papillae - occlusal interferences between $\overline{3}$ and $\underline{2}$ - may result in discrepancy of midline - risk of space reopening (consider fixed bonded retainer) - can be difficult to achieve good occlusal fit - gingival recession, open interproximal embrasures Useful assessments - prior to Xtn consider diagnostic set up and Bolton analysis (lower labial tooth width excess is favourable)	Kokich & Shapiro, 1984 Canut, 1996 Bahreman, 1977 Tuverson, 1980 Riedel et al., 1992 Lv et al., 2010 Zhylich & Sunjay, 2011 Hegarty & Hegarty, 1999 Sheridan & Hastings, 1992 Faerovig & Zachrisson, 1999 Dacre, 1985 Zhylich & Sunjay, 2011 Bolton, 1958
Lower canine	- rarely extracted because of the functional importance of this tooth and its good root length - can be difficult to achieve a good lower 2-4 contact - considered if ectopic	
Lower first premolars	Indications for Xtn - tooth most commonly extracted for relief of moderate-severe lower arch crowding (59%) - in CI I malocclusions spontaneous improvement in dental arch relationship occurs with age if premolars are extracted in mixed/early permanent dentition	Bradbury, 1985 Persson et al., 1989

	- usefully sited to relieve anterior crowding and to correct molar relationship - serial Xtns and late premolar Xtns resulted in similar final occlusal outcomes with FA; serial Xtns ↓ treatment time but significantly ↑ observation time prior to active treatment - spontaneous improvement is rarely sufficient to correct CI II molar relationship, active treatment is required - approximately 60% of lower 5/3 contact points are satisfactory without active treatment - Xtn of 4's ↑ chance of 3rd molar eruption - in CI III cases to allow camouflage (retroclination of LLS) Contraindications for Xtn - other teeth of poor prognosis - mild crowding - risk of excessive lingual movement of lower incisors	O'Shaughnessy et al., 2011 Stephens & Lloyd, 1980 Crossman & Reed, 1978 Salehi & Danaie, 2008
Lower second premolars	Indications for Xtn - for relief of mild-moderate crowding - may avoid excessive lingual movement of lower incisors (which may occur with first premolar Xtn), alters anchorage balance - better sited than first premolar for correction of molar relationship and posterior crowding - where some 5s are developmentally absent - symmetrical loss of remaining second premolars may be sensible - autotransplantation to lost central incisors spaces Contraindications for Xtn - FA usually necessary to establish good 6-4 contact	Tulloch, 1978 Waterhouse et al., 1999
Lower first molar (see section on Permanent First Molars of Poor Prognosis)	Indications for Xtn - never tooth of choice to Xtn - functionally important - if tooth is carious consider the following: <i>severity of crowding:</i> <i>Spaced</i> - try to restore the tooth if possible <i>Mild-moderate crowding</i> - extract the tooth <i>Moderate-severe crowding</i> - wait until definitive planning in permanent dentition before Xtn ↑ eruption spaces for 3rd molars and ↓ their impaction <i>stage of development of 2nd molar:</i> - ideal timing is between crown complete to 1/3 root formed, i.e. when the bifurcation of roots are forming <i>status of the other first permanent molars:</i> - extract all? - do not worry about balancing in the lower arch - do consider compensating because 6 will overerupt Contraindication for Xtn - late Xtn of first molars results in rotation and mesial tipping of lower second molar tooth - missing 3rd molars - side effects during mesialisation of 2nd molars without skeletal anchorage resulted in posterior displacement of soft tissue and changes in profile	Gill et al., 2001 Bayram et al., 2009 Jacobs et al., 2011
Lower second molar	Indications for Xtn - relief of molar crowding - early permanent dentition with a minimally crowded/ well aligned lower arch, 3rd molar impaction likely - Xtn in early permanent dentition may prevent or at least limit late lower arch crowding	Richardson, 1983, 1985

	- relief of premolar crowding - vertically impacted premolar in the line of the arch - early Xtn indicated for spontaneous correction - removal impacted 2nd molars provided 3rd molar present Contraindications for Xtn - developmental absence or diminutive 3rd molar - lower anterior crowding >1-2mm Advantages of second molar Xtn - obviate the need for surgical removal of 3rd molar: - financial and pt morbidity considerations - shorter treatment = unsubstantiated - facilitation of OB reduction = unsubstantiated Disadvantages of second molar Xtn 3rd molars may erupt into an unsatisfactory position, rarely with proper angulation and contact relationship - wide discrepancy between studies on the number of unsatisfactory 3rd molar eruptions: 25% Cryer, 20% Dacre, 4% Richardson - difficult to predict which 3rd molars will erupt unsatisfactorily - second course of treatment to orthodontically upright the 3rd molar may be required - Xtn site located far from area of concern in moderate-severe anterior crowding	Richardson & Burden, 1992 Kenrad et al., 2011 Bishara & Burkey, 1986 Gooris et al., 1990 Cryer, 1967; Dacre, 1987; Richardson & Richardson, 1993 Thomas & Sandy, 1995 Orton & Jones, 1987 Hatami & Dreyer, 2019
Upper central incisor	- never the tooth of choice to extract unless pathology - if lost early due to caries or trauma, consider space maintenance until definitive treatment plan - if lost can consider: - replacement with lateral incisor - transplant	Crawford et al., 2008 Czochrowska et al., 2003; Barber et al., 2020
Upper lateral incisor	Indications for Xtn - if peg shaped, small or invaginated - if contralateral <u>2</u> is developmentally absent - if root is severely resorbed from ectopic <u>3</u> - if <u>2</u> is severely crowded and <u>1</u> and <u>3</u> are in acceptable contact Contraindications for Xtn - aesthetic considerations: - if <u>3</u> crown is bulbous - if <u>3</u> crown is different shade to <u>1</u> - if <u>3</u> gingival margin height differs significantly from <u>1</u> - CI III incisal relationship - unfavourable anchorage balance	
Upper canine	Rarely tooth of choice to extract: - aesthetic - canine eminence important although no difference in smile attractiveness between max canine Xtn and premolar Xtn as assessed by general dentists, lay people and orthodontists - functionally important - canine guidance - long root - useful restoratively 2-4 contact is not ideal - occlusal interferences Indications for Xtn - if <u>24</u> are in good contact and <u>3</u> is crowded from the line of the arch - if <u>3</u> is in an ectopic position, unfavourable for alignment - if <u>3</u> is becoming cystic (pathological)	Thiruvengkatachari et al., 2017
Upper first premolars	Indications for Xtn - commonest tooth to extract for upper arch crowding - space is conveniently positioned to ↓ OJ	Bradbury, 1985

	• apart from <u>6</u> it is the first tooth to erupt in the buccal segment - early Xtn is possible • <u>35</u> contact is generally considered acceptable	
Upper second premolar	Indications for Xtn • extracted in preference to the <u>4</u> if crowding or OJ is less severe in upper arch • Xtn of <u>5</u> rather than <u>4</u> may avoid over retraction of the labial segment - useful with CI III malocclusions • if <u>5</u> is excluded from the arch, e.g. if early loss of E • if <u>5</u> is small or hypoplastic • if good interproximal contact exists between <u>4</u> and <u>6</u> • autotransplantation to lower 5's has good prognosis Contraindication for Xtn • FA often necessary to establish satisfactory contact between 4 and 6	Josefsson et al., 1999
Maxillary first molar (see section on Permanent First Molars of Poor Prognosis)	• as with the lower first molar this is rarely the tooth of choice to extract Indication for Xtn • hypoplastic, carious, large restoration • as a compensating Xtn if lower first molar removed • enforced due to caries then balancing and compensating Xtn should be considered but not essential • timing of Xtn is less critical than in lower arch to obtain an acceptable <u>5-7</u> contact; 7 crown is able to rotate anteriorly about its roots and usually develops distally angulated so can 'swing' down into correct position • can relieve posterior crowding (molar stacking) • check morphology and presence of 8	
Maxillary second molar	Indications for Xtn • to aid distal movement of the upper buccal segments with EOT (good co-operation with HG essential) • 1-2mm more distal movement of <u>6</u> when <u>7</u> Xtn and 5° less upper incisor proclination • not indicated for relief of anterior crowding or OJ ↓ • generally accepted that 3rd molars erupt into satisfactory contact with first molar • accelerated eruption of 3rd molar into acceptable position often occurs • ↑ eruption spaces for 3rd molars and ↓ their impaction Contraindications for Xtn • heavily restored first molar • developmentally absent 3rd molar	Waters & Harris, 2001 Quinn, 1985; Bishara & Burkey, 1986 Moffit, 1998 Bayram et al., 2009
Third molars	• 13-15% of pts never develop mand third molars • 17.5-25% of 3rd molars become impacted • prevalence of impaction may be ↑ because fewer teeth extracted due to caries • in orthodontic pts who do not have lower 3rd molars Xtns: → 35% have mesio-angular impaction → 20% have disto-angular impaction • factors contributing to early eruption of 3rd molar: i. low initial angulation of lower 3rd molar to mandibular plane ii. a large ↓ in this angle iii. a large amount of mandibular growth iv. Xtn of a tooth from the corresponding buccal segment particularly a molar	Robinson & Vasir, 1993 Robinson, 1994 Richardson, 1996

	• much debate in the literature about when to extract - most consider that prophylactic surgery should be abandoned • review article concluded that mand 3rd molar only has weak association with late crowding of lower incisors • long term review found no difference in incisor crowding between groups where 3rd molars were impacted, erupted into function, developmentally absent or extracted • effects of early Xtn of lower 3rd molar on late crowding: no significant difference in incisor crowding between Xtn and non-Xtn groups • late lower incisor crowding is insufficient reason alone to remove mandibular 3rd molars - 10% have transient lingual nerve impairment - 1% have permanent lingual or ID nerve impairment Indications for removal • to allow uprighting of impacted lower 7 • teeth that present with symptoms other than transiently associated with eruption • teeth unlikely to contribute to occlusal function and whose position jeopardises the continuing health of surrounding tissues: i. resorption of second molar ii. follicular cyst iii. bone loss due to chronic periodontitis iv. concealed caries in distal surface of 2nd molar	Shepherd & Brickley, 1994 Robinson & Vasir, 1993 Ades et al., 1990 Harradine et al., 1998 Robinson, 1994; NICE 2000; RCS, 2020
Recommended reading	Royal College of Surgeons Faculty of Dental Surgery (RCS), 2020	

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Removable Appliances

Definition	Appliances which can be removed from the mouth by pt	
Mode of action	Tip teeth around fulcrum at centre of resistance: - centroid (40% from apex) for single rooted teeth - trifurcation of <u>6</u>	
Material	- baseplate: acrylic - wires: SS, Elgiloy	
Design	A - Active components R - Retention A - Anchorage B - Baseplate	
Common components	Active <i>bite planes</i>: - anterior and posterior <i>springs</i>: - Z-springs (0.5mm SS), needs good ant retention - T-springs (0.6mm SS), needs capping for crossbite correction - palatal springs (0.5mm SS <u>1-5</u>, 0.6mm SS <u>6</u>), move teeth mesially or distally; helix ↑ length of wire, this is point of activation - buccal springs (0.7mm SS, sleeved 0.5mm SS) - Roberts retractor (0.5mm SS with sleeving) - labial bow ± split (0.7mm SS), trim acrylic palatal to incisors if retracting - springs should deliver force perpendicular to tooth, through a surface parallel to it; should also direct force as close to centre of resistance as possible - longer wire = lighter force, larger radius or deflection = larger force 0.7mm SS activated by 1mm = 0.5mm SS activated by 3mm $F \propto \frac{4dr}{3l}$ (F=force, d=deflection, r=radius, l=length) <i>expansion</i>: - screws (0.2mm/turn) - coffin spring (1.25mm SS), activate by pulling 2 halves apart Retention <i>clasps</i>: - Southend (0.8mm Elgiloy, 0.7mm SS) - C-clasps (0.7mm SS) - Adam's crib (0.7mm SS permanent, 0.6mm SS primary teeth) - ball-ended clasps - Plint clasp (flyover) (0.7mm SS) <i>others</i>: - labial bow ± acrylation (0.7mm SS) Anchorage - consider: - root surface area - palatal vault - extra-oral Baseplate - complete - segmented - anterior bite plane - buccal capping	

Advantages	• relatively cheap • simple, easy to adjust • oral hygiene easier than with FA • can move teeth in blocks	Littlewood et al., 2001
Disadvantages	• compliance needed • move only few teeth at a time • tipping movements only • retention • limited use in lower arch • rotations difficult to treat • affects speech • intermaxillary traction not practicable	Shah, 2017
Common uses	• space maintainers • retainers • functional appliances • expansion: AP and laterally; average treatment time was significant shorter, less expensive than quadhelix • simple treatment (tipping teeth) • support distal movement • bite planes • correction of anterior and posterior crossbite	Godoy et al., 2011
Other uses	• constricting the mandibular arch • discouraging digit-sucking, tongue-thrust • extrusion of incisors or other teeth • buccal capping for intrusion of buccal segment • Nudger appliance - distalise buccal segment in conjunction with HG	Liu et al., 2011 Kulkarni & Lau, 2010 Darby et al., 2009
Common problems	• slow rate of tooth movement • breakages • excessive tilting • anchorage loss • palatal inflammation • co-operation	Mitchell, 2007 Al-Moghrabi et al., 2017
Recommended reading	Littlewood et al., 2001	

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Fixed Appliances

Definition	Appliance which is fixed to the teeth and cannot be removed by pt	
Mode of action	• applies a mechanical force couple to crown • in conjunction with simple forces can achieve derotations, apical and bodily movements	
History	• Edgewise appliance introduced by Edward Angle in 1928 • Begg appliance introduced by Raymond Begg in 1950's • preadjusted Edgewise appliance introduced by Larry Andrews in 1970's after studying the occlusion of 120 non-orthodontic normals → 'Straight-Wire' appliance • 'Tip-Edge' appliance developed by Peter Kesling • lingual appliance developed by Kurz 1970's	Angle, 1928 Begg, 1956 Andrews, 1972, 1979; McLaughlin & Bennett, 1989 Kesling, 1988 Proffit et al., 2012
Types	Buccal • <i>advantages</i> - good access, ease of work, ↓ working time, excellent finishing and detailing • <i>disadvantages</i> - poor aesthetics, decalcification visible Lingual • <i>advantages</i> - good aesthetics, decalcification not visible, good bite opening • <i>disadvantages</i> - difficult access to make adjustments, ↓ interbracket span, ↑ working time, pt discomfort, more difficult finishing and detailing	Auluck, 2013 Singh & Cox, 2011 Singh & Cox, 2011
Components	For greater details (see sections on Brackets and Archwires) • brackets • archwires • accessories	
Bracket systems	• preadjusted Edgewise appliance, e.g. MBT • 'Tip-Edge' appliance • standard Edgewise appliance • Begg appliance • lingual appliance, e.g. 'Incognito' Preadjusted edgewise appliance is the most common appliance system used in USA	Andrews, 1976 Kesling, 1988 O'Connor, 1993
Preadjusted Edgewise system	Philosophy based on • ideal bracket system • ideal force delivery system (sliding mechanics) Slot size • 0.018" x 0.028" - working archwire 0.016" x 0.022" SS • 0.022" x 0.028" - working archwire 0.019" x 0.025" SS • no difference in treatment outcomes with 0.018" or 0.022" • 0.022" x 0.030" (bioprogressive technique, Ricketts) Prescriptions • "ideal" final tooth positions incorporated into bracket slots, i.e. the brackets' prescription • a number of prescription available: Andrew's, Roth's, Alexander, MBT • MBT prescription has: - more +ve torque in ULS and more -ve torque in LLS to resist the effects of CII elastic use - ↓ lingual crown torque in lower molar prescription to resist lingual rolling with CII elastics - ↓ mesial crown tip in upper canine prescription is less anchorage demanding in AP	Andrews, 1976, 1979 Yassir et al., 2019 Andrews, 1976; Alexander, 1986; McLaughlin et al., 2002 Moesi et al., 2013

	- most common prescriptions: <table> <tr><td><u>Andrew's</u></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr> <tr><td>tip</td><td>5</td><td>5</td><td>2</td><td>2</td><td>11</td><td>9</td><td>5</td></tr> <tr><td>torque</td><td>-9</td><td>-9</td><td>-7</td><td>-7</td><td>-7</td><td>3</td><td>7</td></tr> <tr><td>TOOTH</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td></tr> <tr><td>torque</td><td>-30</td><td>-30</td><td>-22</td><td>-17</td><td>-11</td><td>-1</td><td>-1</td></tr> <tr><td>tip</td><td>2</td><td>2</td><td>2</td><td>2</td><td>5</td><td>2</td><td>2</td></tr> </table> <table> <tr><td><u>Roth's</u></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr> <tr><td>tip</td><td>0</td><td>0</td><td>0</td><td>0</td><td>11</td><td>9</td><td>5</td></tr> <tr><td>torque</td><td>-14</td><td>-14</td><td>-7</td><td>-7</td><td>0</td><td>8</td><td>12</td></tr> <tr><td>TOOTH</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td></tr> <tr><td>torque</td><td>-30</td><td>-30</td><td>-22</td><td>-17</td><td>-11</td><td>-1</td><td>-1</td></tr> <tr><td>tip</td><td>-1</td><td>-1</td><td>0</td><td>0</td><td>6</td><td>0</td><td>0</td></tr> </table> <table> <tr><td><u>MBT</u></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr> <tr><td>tip</td><td>5</td><td>5</td><td>0</td><td>0</td><td>8</td><td>8</td><td>4</td></tr> <tr><td>torque</td><td>-14</td><td>-14</td><td>-7</td><td>-7</td><td>-7</td><td>10</td><td>17</td></tr> <tr><td>TOOTH</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td></tr> <tr><td>torque</td><td>-10</td><td>-20</td><td>-17</td><td>-12</td><td>-6</td><td>-6</td><td>-6</td></tr> <tr><td>tip</td><td>2</td><td>2</td><td>2</td><td>2</td><td>3</td><td>0</td><td>0</td></tr> </table> Morphology - brackets - siamese - standard, minitwin, minitwin with vertical slot - single wing - e.g. Attract - self-ligating - e.g. Damon, In-Ovation R, SmartClip - bands: standard/micro; convertible tube/bracket Materials - SS - ceramic - polycarbonate - zirconia Accessories - many, e.g. derotation wedges, Steiner wedges, elastic chain, NiTi springs, Elgiloy coil spring Advantages ↓ wire bending - sliding mechanics allowed - good finishing Disadvantages - ignores biological variability ↑ friction hence ↑ anchorage considerations	<u>Andrew's</u>								tip	5	5	2	2	11	9	5	torque	-9	-9	-7	-7	-7	3	7	TOOTH	7	6	5	4	3	2	1	torque	-30	-30	-22	-17	-11	-1	-1	tip	2	2	2	2	5	2	2	<u>Roth's</u>								tip	0	0	0	0	11	9	5	torque	-14	-14	-7	-7	0	8	12	TOOTH	7	6	5	4	3	2	1	torque	-30	-30	-22	-17	-11	-1	-1	tip	-1	-1	0	0	6	0	0	<u>MBT</u>								tip	5	5	0	0	8	8	4	torque	-14	-14	-7	-7	-7	10	17	TOOTH	7	6	5	4	3	2	1	torque	-10	-20	-17	-12	-6	-6	-6	tip	2	2	2	2	3	0	0	
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'Tip-Edge' system	Philosophy - free crown tipping followed by root uprighting - use of light forces Slot size - maximum dimensions → open - 0.028" x 0.028" closed - 0.022" x 0.028" - working archwire 0.0215" x 0.025" SS 3 stages of treatment - Stage I: align teeth, correct incisor and molar relationships, crossbite and rotations - Stage II: space closure and maintain Stage I corrections - Stage III: correct inclinations of teeth Prescription <table> <tr><td>final tip</td><td>0</td><td>0</td><td>11</td><td>9</td><td>5</td></tr> <tr><td>torque</td><td>-7</td><td>-7</td><td>-4</td><td>8</td><td>12</td></tr> <tr><td>TOOTH</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td></tr> <tr><td>torque</td><td>-20</td><td>-20</td><td>-11</td><td>-1</td><td>-1</td></tr> <tr><td>final tip</td><td>0</td><td>0</td><td>5</td><td>5</td><td>2</td></tr> </table> Accessories - mainly used in Stage III	final tip	0	0	11	9	5	torque	-7	-7	-4	8	12	TOOTH	5	4	3	2	1	torque	-20	-20	-11	-1	-1	final tip	0	0	5	5	2	Kesling, 1988																																																																																																																		
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	- many, e.g. uprighting springs, torque bars/auxiliaries, derotation springs, elastic chain - Tip-Edge Plus brackets have a 'deep tunnel' - 0.014" NiTi can be placed in this to facilitate tip/torque delivery Advantages - allows tipping ↓ friction in early stages ↑ inter-bracket span - progressive torque addition - precision in finishing Disadvantages - reliant on elastic wear and Xtn philosophy - poor rotational control ↑ friction in later stages - complex in Stage III (although sidewinders not required with Tip-Edge Plus) Comparison of Pre-adjusted Edgewise and Tip-Edge - prospective study comparing canine retraction rates found no significant difference found between the 2 appliances, ↓ anchorage loss in Tip-Edge pts BUT canines not fully uprighted	Parkhouse, 2007 Lotzof et al., 1996
Edgewise appliance	- horizontal slot in bracket - tooth movement achieved by bodily movement ↑ wire bending to achieve final tooth position - precision in finishing allowed ↑ forces used - largely replaced by preadjusted edgewise systems	Angle, 1928
Begg appliance	- based on the use of light forces and tipping teeth - bracket has vertical slot in which archwire is secured with brass pins 3 stages of treatment: - Stage I: align teeth, correct incisor and molar relationships, crossbite and rotations - Stage II: space closure and maintain Stage I corrections - Stage III: correct inclinations of teeth ↓ friction - largely replaced by 'Tip-Edge' appliance	Begg, 1956 Kesling, 1988
Lingual Appliances	- these can be directly bonded, e.g. In-ovation L, or custom made and indirectly bonded, e.g. Incognito Advantages - excellent aesthetics ↓ enamel decalcification and what occur is ↓ visible - better OB reduction - anchorage control Disadvantages - difficulties in bracket placement and adjustment - short interbracket span ↓ flexibility in tooth movement - speech can be affected - problems in cleaning ↑ pt discomfort initially particularly to the tongue and soft tissues - longer operator chair-time	Singh & Cox, 2011; Auluck, 2013 van der Veen et al., 2010 Khattab et al., 2013 Slater, 2013
Semi-customed appliances	more variability than fully programmed appliance but are <i>not</i> fabricated specifically to a pt's needs, e.g. BEDDTIOT uses mixed prescription Straight-Wire appliances	Hocevar, 1985
Fully-customed appliances	designed for specific needs of the pt's malocclusion, e.g. - Ormco Insignia - custom brackets, buccal tubes and archwire with indirect bonding	Andreiko, 1994

	- Incognito - custom-made lingual appliance - disadvantage - high cost, more planning time required, no evidence that system ↓ treatment time or quality - recent interest and developments in this area	Wiechmann et al., 2003 Penning et al., 2017
Self-ligating (SL) appliances	- do not require any external form of ligation - can be passive, e.g. Damon, or active, e.g. Inovation R ↓ chairside time - no evidence of improved efficiency, faster alignment, more stable or superior aesthetic result with Damon - mainly prospective research and systematic reviews have shown no difference in rate of initial alignment or space closure when compared to conventional brackets - RCT compared conventional appliance, active SL and passive SL showed that alignment is faster with conventional and no difference in space closure - no benefit proven and associated with longer treatment duration	Wright et al., 2011 Wright et al., 2011 Chen et al., 2010; Fleming & Johal, 2010 Songra et al., 2014 Papageorgiou et al., 2014
Problems (see sections on iatrogenic damage, Intra- and Extra-oral damage and Systemic effects)	Geometric play - the amount of play between archwire and bracket slot affects third order (torque) expression and depends theoretically on the dimensions of bracket and archwire - however, imperfections in manufacturing process and incomplete ligation ↑ the measured play degrees of play (theoretical / measured) .016" x .022" SS in .018" slot: 9.5° / 14.1° .017" x .025" SS in .018" slot: 6.0° / 6.2° .018" x .025" SS in .022" slot: 15.2° / 20.1° .019" x .025" SS in .022" slot: 10.5° / 14.5° Lower incisor proclination versus crowding - degree of lower incisor proclination following non-Xtn treatment is complicated by variable features of malocclusion, e.g. curve of Spee, arch expansion, tooth size discrepancy McLaughlin et al: 1mm relief of crowding = 1.25° lower incisor proclination; not based on a study but on authors' clinical experience Yitschaky et al: 1mm relief of crowding = 0.5° lower incisor proclination; retrospective study but low coefficient of determination, meaning findings cannot be reliably used as a prognostic tool for individual cases, but rather as a general guiding principle	Fleming & Seehra, 2019 Gioka & Eliades, 2004; Arreghini et al., 2014 McLaughlin et al., 2002 Yitschaky et al., 2016
Recommended reading	Andrews, 1972, 1976; Kesling, 1988; McLaughlin et al., 2002; Auluck, 2013; Papageorgiou et al., 2014; Fleming & Seehra, 2019	

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Headgear (HG)

Definition	Means of applying force to teeth/Sk structures from an extraoral source	
History	- introduced in late 1800's - abandoned as intra-oral elastics thought to be as good - reintroduced in 1940's after cephalometric R/G demonstrated effect of elastics - currently over 1/3 of orthodontists reinforce anchorage with HG however this may be ↓ with more widespread use of TADs	Angle, 1900 Oppenheim, 1936 Banks et al., 2010 Li et al., 2011
Classification	distalising HG - direction of elastic traction has a distal component Types: Occipital directed (high) pull Combination directed pull Cervical directed (low) pull (J-hook HG - rarely used) asymmetric HG - for differential molar movement Four methods of ↑ unilateral force: 1) longer facebow arm on side requiring more movement, or Equal arm lengths but: 2) 15° more angulation on side requiring more movement 3) asymmetrically activated transpalatal arch 4) outer bow soldered to the inner bow unilaterally HG to mand - conventional HG, chin caps	Martina et al., 1988 Squeff et al., 2009 Graber, 1977; Orton et al., 1983
Components	- head cap/neck strap - facebow, e.g. Kloeß bow, Nitom bow - safety mechanisms (at least 2) - elastics - removable/FA - chin caps	Postlethwaite, 1989; 1990 Graber, 1977
Uses	Dental - anchorage - distalisation - single or blocks of teeth - intrusion - single or blocks of teeth - extrusion - single or blocks of teeth - asymmetric movement Skeletal - growth modification Max - <i>suppression</i>, 1-2mm over 10yrs which is permanent even after treatment has ceased Mand - <i>suppression</i>, retrusion of the chin during chin cap treatment, but catch-up mandibular growth may occur during or after the pubertal growth period; contradictory evidence exists - favourable dentoskeletal outcomes achieved with mandibular cervical HG were maintained over 5yrs review	Atherton et al., 2002 Firouz et al., 1992 O'Reilly et al., 1993 Martina et al., 1988 Mills, 1978; Wieslander, 1993 Sugawara et al., 1990 Baccetti et al., 2009
Factors influencing effect	Direction of force Duration of force - 10-12 hours (anchorage) - 12-14 hours (traction) Magnitude of force - 250-300g per side (anchorage) - 400-500g per side (Sk effect) Centres of rotation - single rooted teeth → centroid 6 → trifurcation - max → between roots of 45	Bowden, 1978a,b Worms et al., 1973 Poulton, 1959

Resolution of forces	Horizontally - force through centre of resistance → bodily movement - force above centre of resistance → distal root tipping - force below centre of resistance → mesial root tipping Vertically - above occlusal plane → intrudes teeth - below occlusal plane → extrudes teeth	Kuhn, 1968; Bowden, 1978a
Problems	Tooth related <i>unwanted tooth movement</i> - tipping - extrusion may cause clockwise rotation of mand → pt becomes more Class 2 but this effect is variable - buccal rolling of 6 with high-pull HG - crossbite development on side of movement with asymmetric HG - lingual tipping of lower incisors, clockwise rotation of mand → ↑ LFH with chin cup therapy <i>root resorption</i> - possibly with J-hook HG Pt related <i>co-operation</i> - many pts 'lie', using headgear calendar ↑ wear by 2.6 hrs/day <i>biological variability</i> - growth may be unfavourable <i>extra/intra-oral injuries</i> <i>pain</i> <i>difficulty with insertion</i> <i>nickel allergy</i> <i>pressure alopecia</i> - due to pressure-induced ischaemia to the scalp	Burke & Jacobson, 1992 Martina et al., 1988 Mills, 1978 Cureton et al., 1993a,b; Cole, 2002 Boecler et al., 1989 Booth-Mason & Birnie, 1988; Samuels & Jones, 1994 Leonardi et al., 2008
Safety	- no single safety HG is best, at least 2 safety mechanisms should be used - should use safety facebow and release mechanism together, e.g. Masel safety strap, snap release system - release mechanism should have short extension and high consistency at release - written instructions must be given to pt advising them not to wear HG if it disengages while they are asleep - risks involved should be explained - told to seek medical advice if problem; infraorbital injuries may be asymptomatic initially but may exacerbate later, can even lead to cavernous sinus thrombosis	Postlethwaite, 1989, 1990; BOS, 2011 Stafford et al., 1998 Samuels et al., 1996 Chaushu et al., 1997
Alternatives	↓ ant tooth retraction and ↑ anchorage loss with HG compared with TADs, onplants and midpalatal implants - HG and midpalatal implants have same effects but ↑ failure rate with HG (16%) compared to midpalatal implant (8%) - intra-oral appliances may be more effective than HG in distalising molars however effect counteracted by anchorage loss - no clinically significant difference in anchorage loss between HG, TADS and Nance	Li et al., 2011 Benson et al., 2007 Jambi et al., 2013 Sandler et al., 2014
Recommended reading	Bowden, 1978a,b; Samuels & Jones, 1994; Benson et al., 2007; BOS, 2011; Jambi et al., 2013	

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Reverse (Protraction) Headgear

Definition	Means of applying anterior directed forces to teeth/Sk structures from an extraoral source	
Components	• facemask, e.g. Delaire-type or rail-style • double intra-oral arch/URA/upper FA • elastics - changed daily	Verdon, 1989
Uses	• Dental Traction - protraction of single or blocks of teeth • Skeletal Growth modifications <i>Max - enhancement</i> - accelerated growth at circummaxillary sutures - modifications at pterygomaxillary suture - bony apposition at maxillary tuberosity - possible to achieve 2mm advancement of max that withstands mand growth if RME and protraction HG used in primary or early mixed dentition - surgically assisted (by incomplete LeFort I) protraction more rapid and effective than protraction assisted by RME - low angle cases demonstrated more forwards max movement - can be successfully used in treatment of max hypoplasia by miniplates (i.e. skeletal pull only, avoiding dental compensations) <i>Mand - suppression</i> - smaller increments in total mandibular length	Nanda, 1978 Baccetti et al., 1998 Franchi et al., 2004 Kucukkeles et al., 2011 Yoshida et al., 2007 Baek et al., 2010
Treatment time	Opinions: • successful forward positioning of max before age 8, over 8yrs orthodontic movement overwhelms Sk changes • similar Sk response obtained when maxillary protraction was started either before age 8 (5 to 8yrs) or after age 8 (8 to 12yrs) • ↑ in maxillary growth only occurs before age 10 • the age at which treatment begins has no effect on long-term success for pts younger than 10yrs, but the % of successful treatment ↓ after that age • meta-analysis of protraction HG effectiveness → it was less effective on pts >10yrs; longer treatment plans and ↑ ULS proclination if palatal expansion not used • some evidence that adjunctive RME does not improve max advancement with protraction HG • early use is skeletally and dentally effective, resulting in 75% success rate (achieving +ve OJ) for CI III pts under 10yrs; after 3yrs ongoing 70% success rate (maintaining +ve OJ), however no psychosocial benefit was gained • Sk gain was lost after 6yrs but 68% of pts maintained +ve OJ; pt's were ↓ likely to be offered orthognathic treatment (1/3 compared with 2/3 in control group) - as this was assessed by treating clinicians there may have been bias	Verdon, 1989 Mermigos et al., 1990 Merwin et al., 1997 Baccetti et al., 1998 Wells et al., 2006 Kim et al., 1999 Vaughn et al., 2005 Mandall et al., 2010 Mandall et al., 2012 Mandall et al., 2016
Factors influencing effect	• Direction of force - force should go through maxillary centre of resistance - point of force application distal to the laterals and inclination 20° to 25° below occlusal plane • Duration of force - only at night - 24 hours a day • Magnitude of force - 300-500g per side	Staggers et al., 1992 Verdon, 1989 Verdon, 1989 McNamara, 1987 Verdon, 1989

Side effects	• forward movement of maxillary teeth • downward and backward rotation of the mand • does not cause TMD	Mandall et al., 2010
Predictors of failure	• large mand • horizontal mandibular growth • pts who experienced a downward and backward rotation of the mand during treatment	Wells et al., 2006
Recommended reading	Verdon, 1989; Mandall et al., 2010, 2012, 2016	

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Alternative Methods for Anchorage Support and Molar Distalisation

Advantages	• avoid risk of serious injury associated with HG • ↑ clinician control • some methods ↓ need for compliance • many different methods described which would suggest no one type is ideal	Mars, 1995 McSherry & Bradley, 2000
Compliance reliant	Removable Functional Appliances (see section on Functional Appliances) • forces generated by stretching muscles, fascia and periodontium • aid molar relationship correction • use in CI II and CI III cases • require motivated growing pt Upper Removable Appliance (see section on Removable Appliances) • 0.6mm palatal finger springs which must not contact buccal surface of molar • southend clasp to aid retention • anchorage from palatal vault • derotation and outward movement of molars results • anchorage loss manifests as ↑ OJ Class II Mechanics • intermaxillary traction to transfer anchorage from one arch to another • CI II molar relationship correction via forward movement of lower molars • reliant on Xtns • important in Begg and Tip-Edge techniques	Lewis & Fox, 1996 Jambi et al., 2013
Non-compliance reliant	Xtns • additional Xtns sometimes used with FA therapy in high anchorage cases, e.g. Xtn of 6's as well as premolars to provide further space and aid molar correction Pendulum Appliance <i>Design</i> • Nance button attached to bands on first premolars • 0.032" TMA distalising finger springs from button inserted into palatal sheaths on molar bands <i>Disadvantages</i> • 0.75mm anchorage loss per 1mm of molar distalisation • anchorage loss manifests as ↑ OJ • high forces used (230g/side) versus small anchorage unit • tipping of molars distally, average 8° • ↑ in lower face height • hygiene problems with Nance button Pendex Appliance <i>Design</i> • Pendulum appliance with midline screw • 0.5mm anchorage loss for every 1mm of molar distalisation • ↑ in OJ as premolars move mesially • variation uses bilateral distalising screws but requires pt compliance <i>Disadvantages</i> • distal tipping of molars by as much as 14.5° Jones Jig and Distal Jet <i>Design</i> • 'Anchorage Unit' - Nance arch bonded to premolars (4/5)	Hilgers, 1992 Ghosh & Nanda, 1996 Byloff & Darendeliler, 1997 Fortini et al., 2004

	• 'Jig Assembly' - 0.030" wire holds NiTi spring and sliding hook • jig assembly inserted into buccal tubes and archwire slot of molar bands • tying sliding hook back compresses the spring activating the appliance • force applied varies between 75-240g but with similar results • many similar designs described in literature Disadvantage • OJ ↑ by 64% of anchorage creation and premolars move mesially by 185% of molar distalisation • more anchorage loss in distalisation phase than pendulum appliance • use of CI II elastics to aid anchorage results in lower molar extrusion - mesial movement of lower incisors equivalent to molar distalisation Herbst appliance • tooth borne fixed functional appliance • see section on Functional Appliances for design Disadvantages • forward displacement of mandibular dentition • frequent breakages • buccal mucosa ulceration due to bulkiness • problems with crown retention Jasper Jumper • tooth borne flexible fixed functional appliance • 'jumper' coil spring provides force • 'jumper' attached to distal of upper molar band and to auxiliary wire on lower FA • many methods of connecting jumper to FAs Disadvantages • breakages a major problem although a breakage rate of 9% has been reported • forward displacement of mandibular dentition Eureka Spring • tooth borne fixed functional appliance to overcome problems of Jasper Jumper • compressed NiTi springs within a piston • piston cylinder attaches to upper molar tube via universal joint and to lower archwire via an open ring clamp • 50 consecutive cases of failed CI II elastics use found that Eureka springs took average of 4mths (2-14) to correct to CI I and change was mostly dento-alveolar Forsus Fatigue Resistant Device • 3-piece telescoping spring for CI II correction • push rod attaches directly to lower archwire distal to the canine teeth, and the spring to the HG tube • >50% breakage rate Saif Springs • NiTi springs tied in as CI II 'elastics' • employs extension traction AdvanSync • tooth borne fixed functional used with fully bonded arches • upper/lower molar attachments with telescopic arm • shown to have more HG effect • advantages: simultaneous molar/OJ correction and alignment, simple re-activation	Brickman et al., 2000; Ngantung et al., 2001 Runge et al., 1999 Papadopoulos et al., 2004 Chiu et al., 2005 Muse et al., 1993 Pancherz, 1979 White, 1994 Blackwood, 1991 Stucki & Ingervall, 1998 Devincenzo, 1997 Stromeyer et al., 2002 Ross et al., 2007 Al-Jewair et al., 2012
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	- disadvantages: OB ↓ and band remove can be difficult (may require high speed handpiece), breakages can be time consuming Bite Fixers - coil springs with a flexible core - more robust than many other fixed CI II devices Magnets - modified Nance appliance using repelling high energy magnets to distalise maxillary molars - samarium-cobalt and neodymium-iron-boron magnets used <i>Disadvantages</i> - can be bulky - high initial force dissipates quickly - large force drop with distance - loss of flux and force in warm environment - have to be activated weekly - force dependent on magnet alignment - superelastic coils more effective for molar distalisation - average anchorage loss 50% - average 9° of molar tipping	Gianelly et al., 1989 Bondemark et al., 1994 Noar & Evans, 1999 Bondemark et al., 1994
Temporary Anchorage Devices (TADs)	See section on Temporary Anchorage Devices (TADS)	
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Temporary Anchorage Devices (TADS)

Definition	Titanium screws in position for short periods of time, which penetrate the gingiva into alveolar bone with the aim of providing temporary Sk anchorage	
History	• osseointegrated implants first reported in late 1960 • first orthodontic use in dogs and found to be stable despite high force • titanium mini-screws first described in 1997 • have ↑ in popularity recently	Brånemark et al., 1969 Roberts et al., 1989 Kanomi, 1997 Harradine, 2014
Types	Midpalatal implants <i>Design</i> • placed in anterior palatal vault to ensure sufficient bone • 3-4mm diameter and 6mm in length • osseointegrated • allow 13 weeks before uncovering and application of force • 92% success rate • palatal implant had ↓ failure rate than miniscrews Disadvantages • careful placement to avoid damage to anterior tooth roots • mean anchorage loss of 0.7-1.1mm when canines retracted 6.5mm in prospective study using palatal implant • inconvenient position for application of force • expensive • may require GA for placement and removal • soft tissue surgery to uncover Onplants <i>Design</i> • subperiosteal titanium disk 2mm thick/10mm diameter • allowed to osseointegrate for 4mths • advantage that can be placed in areas with little bone <i>Disadvantages</i> • not commercially available • two soft tissue surgical procedures needed Mini-screws/mini-implants <i>Design</i> • three major components - the head (various designs) - the transmucosal collar - the intraosseous thread • 1.0mm-2.0mm diameter • 6mm-11mm length depending on site of use • pre-drilling - screws with blunt tip require pilot hole to be drilled before screw can be inserted • self-drilling - screw has sharp tip and no pre-drilling needed - primary stability better - ↑ success rate - less expensive - simpler technique - ↓ risk of root damage - ↑ screw-bone contact <i>Mini-screw insertion</i> • confirm root angulation with R/G before insertion	Tinsley et al., 2004 Männchen & Schätzle, 2008 Schätzle et al., 2009 Männchen & Schätzle, 2008 Cousley & Parberry, 2005 Block & Hoffman, 1995 Cousley, 2015a,b Chen et al., 2008 Kim et al., 2005 Heidermann et al., 2005 Baumgaertel, 2014

• topical anaesthetic or small amount of LA sufficient; topical anaesthetic only can be painful, leading to failure in 42% of sites; LA infiltration 100% success • use small diameter as possible • maxillary buccal insertion sites - between 2nd premolar and 1st molar - between canine and 1st premolar - between central incisors • mandibular insertion sites - between 1st and 2nd premolars - retromolar area • more apical insertion site and 45° insertion → less risk of root damage • keep insertion site in attached mucosa • stop insertion and re-orientate if: - pt reports discomfort - ↑ resistance is met • confirm lack of root damage with 2xPA R/Gs using horizontal parallax • root proximity important for stability <i>Immediate versus delayed loading</i> • immediate loading is feasible; immediate loading with force <200g does not ↓ success rate • if in doubt, especially in adolescents/thin bone, then load very lightly at start • loading can ↑ long-term stability • latency period may be a significant factor, especially in adolescents <i>Mini-screw stability</i> • ↓ when diameter less than 1.1mm • no ↑ stability when diameter >1.6mm • screw length >5mm does not ↑ stability • immediate loading with force <200gm does not ↓ success rates • ↓ success if placed in non-keratinised mucosa • no difference in failure rates when placed just into mucous membrane • meta-analysis found that jaw and root proximity are the only factors associated with failure • jaw, age at insertion, length and diameter influence success • ↑ failure rate in smokers <i>Disadvantages</i> • technique sensitive • only certain sites suitable • potential to fracture - small risk • damage to tooth roots - 21% root contact inexperienced users - 13% for experienced users • risk of failure 10%-20% Mini-Plates <i>Design</i> • T or L shaped - attached by 2 or more screws to zygoma or mand angle - arm extends through mucosa into mouth <i>Advantages</i> • ↓ risk of root damage • force vector can be brought close to occlusal plane • good pt acceptance	Lamberton et al., 2016 Park et al., 2006 Watanabe et al., 2013 Costa et al., 1998 Motoyoshi et al., 2007 Park et al., 2006 Park et al., 2006 Park et al., 2006 Costa et al., 1998 Cheng et al., 2004 Chang et al., 2015 Papageorgiou et al., 2012 Afrashtefar, 2016 Alharbi et al., 2018 Kim et al., 2010 Chen et al., 2008 Cho et al., 2010 Sherwood et al., 2002 Cornelis et al., 2008a
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	• can be used for maxillary protraction • miniplate had ↓ failure rates than miniscrews <i>Disadvantages</i> • GA required for insertion and removal • post operative pain	Schätzle et al., 2009 Cornelis et al., 2008a,b
Applications	Mini-screws/mini-implants <i>Anchorage</i> • anchorage for retracting anterior teeth or protraction of posterior teeth • systematic review has shown better anchorage than HG with less anchorage loss • ↑ anterior tooth retraction with mini-screws than HG • 0.80mm (right), 0.99mm (left) molar anchorage loss with TADs, compared to 1.3 -1.99mm (HG) and 1.84-2.09mm (Nance) although differences not statistically significant <i>Molar distalisation</i> • can successfully distalise maxillary molars in growing and non-growing pts • may be faster due to en-mass distalisation • ↓ round tripping of anterior teeth • no ↓ in OB as some intrusion also occurs • anchorage loss less than 0.5mm <i>Molar intrusion</i> • placed buccally and palatally can be used to intrude maxillary molars • used in mand with lingual arch can intrude mandibular molars • 2 points of force application needed to prevent buccal flaring • can be used to ↓ AOB by >4mm and ↓ MMPA 5° Miniplates • absolute anchorage for molar distalisation in growing and non-growing pts • mandibular molar intrusion up to 5mm • AOB reduction 3mm-4.5mm	Jambi et al., 2014 Li et al., 2011 Li et al., 2011 Sandler et al., 2014 Park et al., 2004b Lai et al., 2008; Park et al., 2004a Park et al., 2004a Umemori et al., 1999 Gelgo et al., 2004 Park et al., 2004a Park et al., 2006 Xun et al., 2007 Cornelis & De Clerck, 2007 Umemori et al., 1999 Sherwood et al., 2002
Contra-indications	• smoking • inadequate oral hygiene • bleeding disorders • generalised or localised bone pathology • endocarditis • immune compromise	
Recommended reading	Papageorgiou et al., 2012; Jambi et al., 2014; Cousley, 2015a,b	

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Functional Appliances

Definition	Removable or fixed orthodontic appliances which use forces generated by the stretching of muscles, fascia, and/or periodontium to alter Sk and dental relationships	
History	- inclined bite plane first used in 19th century (Catalan) - monobloc appliances developed 1902 - active appliance developed from retainers which improved malocclusions, thought they re-educate oro-facial musculature	Robin, 1902 Andresen & Häupl, 1936
Aims	- correction of OJ and OB - buccal segment relationship correction AP and transverse - alter soft tissue environment	
Indications	growing pt - utilise growth potential motivated pt "Classic" case - uncrowded, well aligned CI II/1 on mild/moderate Sk 2 base with no subsequent need for FA commonly used - moderate/severe Sk 2 with normal-low MMPA other uses: - interceptive, e.g. large OJ and psychological trauma - anchorage, e.g. CI II molars - compromise cases, e.g. poor OH with ↑ OJ - CI II/2 cases once converted to CI II/1 - CI III cases	O'Brien et al., 2003a
Contra-indications	non-growing pt care needed with: - high-angle cases with backward mandibular growth rotation, can be used with careful design - AOB - cases with proclined lower incisors, further proclination minimised with incisor capping	Ruf & Pancherz, 1998 Trenouth, 2000
Classification	Various systems myotonic, e.g. Harvold - large mandibular opening (8-10mm), work by passive muscle stretch myodynamic, e.g. Andresen - medium mandibular opening (<5mm), work by stimulating muscle activity passive tooth borne, e.g. Andresen active tooth borne, e.g. Twin block tissue borne, e.g. Fränkel component approach, e.g. hybrid appliance fixed functional, e.g. Herbst	Houston et al., 1993 Proffit et al., 2012 Vig & Vig, 1986 Pancherz, 1979
Types	Twin block - upper and lower removable appliances with bite blocks of 7mm in height and 70° inclination; generally well tolerated, rapid correction (6-9 months), can be re-activated and expanded (with a midline screw) Retention: - upper 4's and 6's - lower 4's and 6's, or if poor retention on 6's, can use a double crib on 4's and 5's +/- upper labial bow - lower incisor capping or ball ended clasps - positive retention (reinforced when pt bites down on blocks) Re-activation - three methods: - laboratory addition of cold-cured acrylic - requires new bite record and pt will be without their appliance - chairside addition of cold-cured acrylic - can be time consuming but no loss of wear	Brennan & Littlewood, 2006

	- upper incisors retrocline 9° even without wire work - lower incisors procline: 8°±7° (Lund & Sandler, 1998) 4.6° ±4° (1.7mm) (Harradine & Gale, 2000) - had lower incisor capping - incorporating a Southend clasp limits this proclination • eruption guidance - directs molar eruption by specific acrylic trimming, e.g. Andresen; alters cant of occlusal plane, allows autorotation of mand to help correct CI II cases, e.g. Harvold • skeletal modification Maxilla <i>amount of growth</i> - restraint; 0.9° reduction SNA - restraint may ↑ after end of treatment - no restraint <i>direction of growth</i> - possibility with Harvold Mandible - method of measurement important and care needed when looking at results; if Co-Gn used: ↑ mand length will be > than A-P measurement in degrees - enhancement of total mandibular length: 4.2mm compared to control, but point B moved 2.1mm more anteriorly, SNB enhanced by 1.6° <i>↑ growth rate</i> - ↑ 1.5mm/yr more growth in 9-10yr olds, ↑ 1mm/yr more growth in 10-12yr olds - thought to be future growth overdraft, long-term mand is genetically determined size <i>↑ total amount</i> - approximately 1-2mm/yr more which amounts to 0.6° - average ↑ in total mand length found to be 1.79mm, Sk changes were statistically significant, but unlikely to be clinically significant for short term mand growth - extra mand growth if treated during puberty compared to historical control - extra 1mm horizontal growth, 14% of average OJ ↓ - 4.2mm more mand growth at end of treatment period in comparison to control - favourable mand growth in 83% children treated with modified Bionator but 31% controls also had favourable mand growth - statistically significant ↑ in mand length over treatment period with Bass, Bionator and TB - TB → accelerated mand growth initially during treatment but ↓ mand growth in post-treatment period - no long term Sk gain - Sk effects of early treatment not maintained - no long term difference in Sk effects between functional and FA treatment <i>alter growth direction</i> - principally in vert direction <i>alter position of glenoid fossa</i> • YES • NO	Illing et al., 1998 Lund & Sandler, 1998; Harradine & Gale, 2000 Trenouth & Desmond, 2012 Wieslander, 1993; Mills & McCulloch, 1998 Pancherz & Anehus-Pancherz, 1993 Keeling et al., 1998 Mills & McCulloch, 1998 Marschner & Harris, 1966 Pancherz & Fackel, 1990 Lagerstrom et al., 1990; Mills, 1978 Marsico et al., 2011 Christine et al., 2000 O'Brien et al., 2003b Mills & McCulloch, 1998 Tulloch et al., 1997a,b Illing et al., 1998 DiBiase et al., 2019 Pancherz & Hansen 1986; De Vincenzo; 1991; Tulloch et al., 1998 Tulloch et al., 1998 Dolce et al., 2007 Mills, 1991 McNamara, 1973 Mills, 1991; Pancherz & Fischer, 2003
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	<i>condylar position change</i> - initially forward movement within fossa then relapse - 'effective TMJ growth' encompasses changes in condylar growth, condylar position and glenoid fossa displacement - little long-term change Summary - temporary improvement in Sk relationship induced - little evidence that clinically significant permanent Sk alteration results, i.e. short-term effects - Sk pattern enhancement is modest - long term max restraint possible • soft tissue effect - variable, Fränkel reported to 'retrain' muscles - ↑ in lower lip protrusion and length, and ↑ lower face height in short term • incremental advancement - no advantage overall but may have clinical advantage when full protrusion not possible	Pancherz, 1991 Baltromejus et al., 2002 Chintakanan et al., 2000 Dermaut & Aelbers, 1996 Tulloch et al., 1998; Cacciatore et al., 2019 Bishara & Ziaja, 1989 Morris et al., 1998 Devincenzo & Winn, 1989; Banks et al., 2004
Choice	Depends on: Pt factors • age • compliance • malocclusion Clinician factors • preference/familiarity • laboratory facilities	
Success	• with Herbst appliance overall correction: 30-40% orthopaedic movement 60-70% dentoalveolar change • studies with Andresen demonstrated: 35% success; 31% some progress; 34% no progress • prospective RCT of functional treatment demonstrated: 83% favourable mand growth in functional group 31% favourable mand growth in control group • older pts had 34% failure rate, younger pts 19% • similar Sk and dental changes achieved with part-time compared with full-time wear	Pancherz, 1984 Cohen, 1981 Tulloch et al., 1997a,b O'Brien et al., 2003a Parekh et al., 2019
Outcome prediction	• ideally limit functional appliance therapy to pts with: - a mild to moderate ↑ in OJ, up to 11mm - an ↑ in OB - active facial growth - willingness to comply • success with TB could only be related statistically to ↑ in initial OB and ↓ SNB • start age of <12.3yrs significantly improves cooperation • may not ↓ incidence of trauma in those who have already experienced upper incisor trauma • low to moderate level evidence suggests ↓ in incidence of trauma with early treatment	Barton & Cook, 1997 Caldwell & Cook, 1999 Banks et al., 2004 Koroluk et al., 2003 Batista et al., 2018
Use of functionals in the UK	• Clark TB most popular (75% of functionals) • Clark TB associated with the most compliance • 99% of orthodontists use functionals to treat CI II/1 • 63% of orthodontists use functionals to treat CI II/2 • 16% of orthodontists use functionals to treat CI III	Chadwick et al., 1998
Compliance	• non-compliance is defined as those pts who refuse treatment despite all efforts to engage them	Ghafari et al., 1998

	- compliance seems to explain little of the variation in treatment response - retrospective comparison of two designs of TB appliances in 200 consecutive pts found 82.5% of pts fully ↓ their OJ; 9% failed to ↓ OJ below 6mm - RCT investigating part- and full-time wear demonstrated mean durations of 8.78 hours a day (PT group) and 12.38 hours (FT group) - failure rate with TB: 14% (Morris et al., 1998, Gill & Lee, 2005) 34% in older pts & 19% in younger pts (O'Brien et al., 2003a) - failure with Dynamax 28% - comparison of early treatment HG and Fränkel of CI II/1: 42% of females and 24% of males unco-operative with Fränkel appliance - comparison 3x better before 12.3yrs old	Tulloch et al., 1998 Harradine & Gale, 2000 Parekh et al., 2019 Morris et al., 1998; Gill & Lee, 2005; O'Brien et al., 2003a Morris et al., 1998 Ghafari et al., 1998 Banks et al., 2004
Stability	Most work undertaken on Herbst appliance - maxillary changes more stable than mandibular changes - most due to dentoalveolar changes: 58% dental relapse 42% Sk relapse - good buccal interdigitation ↓ dental relapse	Wieslander, 1993 Pancherz, 1991 Pancherz & Fackel, 1990
Two stage vs one stage treatment	- comparison of functional and FA versus FA and HG: - two stage treatment 18mths longer (including pause) - no significant difference in morphology at end of treatment - Bionator treatment in pubertal growth spurt → 3.9mm enhancement of ant pogonial growth compared to controls - comparison of early TB (average aged 9) and one course FA in adolescence: - in the long term no differences in the Sk pattern - functional group profiles perceived to be more attractive - control group (one course FA) finished with same psychological improvement as functional group - early treatment generally not justified unless pt is being bullied and would benefit psychologically	Liveratos & Johnston, 1995 Tulloch et al., 2004; Turpin, 2007 Franchi et al., 2013 O'Brien et al., 2009a O'Brien et al., 2009b
Problems	- compliance - most procline lower incisors and retrocline upper incisors 5-8° ± 7° proclination found with TB - lateral open bites created with TB and Harvold due to rapid correction - Fränkel fragile and prone to breakage - no detailed finishing allowed - may require 2nd phase of treatment which may lengthen overall treatment time - biological variability - do not all work in all pts - relapse	Sahm et al., 1990 Pancherz, 1984 Lund & Sandler, 1998 Livieratos & Johnston, 1995 Mills, 1991 Pancherz, 1991
Research problems	- small samples - poor/no controls - different appliances compared and lengths of study - poor follow-ups - different interpretation of same data - inaccuracies in measurements - animal studies comparable to humans - animals do not have malocclusions, high forces used - these problems have largely been overcome in a multi-centred RCT but still not perfect model	Tulloch et al., 1990 Aelbers & Dermout, 1996 O'Brien et al., 2003a,b,c

	- statistically significant findings may not be clinically relevant - Cochrane review used meta-analysis model which may overestimate statistical certainty of treatment effect	Batista et al., 2018
Recommended reading	Mills, 1978, 1991; O'Brien et al., 2003a,b,c; DiBiase et al., 2015; Batista et al., 2018	

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Definition	Removal clear thermoplastic aligners used in sequence to move teeth to predetermined positions and often referred to as clear aligner therapy (CAT)	
History	- aligners are an extension of the use of tooth positioners developed by Dr H Kesling and manufactured by TP Orthodontics (1945) - thermoplastic material introduced initially for “suck down” retainers and then modified for minor tooth movements - in 1998 Align Technology was granted FDA approval of Invisalign for orthodontic use - rapid development with use of computer technology (CAD-CAM) stereolithography, tooth-movement simulation software and 3D printing - currently over 30 different manufacturers, some marketed as direct to pt plus “in-house”/laboratory 3D printing options available	Kesling, 1945 Sheridan et al., 1995 Weir, 2017
Materials	- scanned polyvinyl siloxane impressions or more commonly direct intra oral scans are manipulated by tooth moving software to predefined sequential tooth positions to which a series of aligners are constructed - transparent thermoplastic materials of varying thickness ranging from 0.5 to 1.5mm and flexibility are formed to each sequential tooth position - most manufacturers use polyethylene terephthalate glycol-modified (PET-G) polypropylene, polycarbonate, polyurethanes or ethylene vinyl acetate - attachments (composite resin shapes bonded to teeth) to aid retention and assist more complex tooth movements such as rotation and extrusion	Skaik et al., 2019 Dasy et al., 2015 Simon et al., 2014
Mode of action	- dependent upon the amount of sequential tooth movement programmed by various algorithms and the thermoplastic material used, force levels are delivered within acceptable orthodontic force ranges - often relies upon IPR and placement of attachments - pts encouraged to wear the aligners at least 20 hrs/day and aligners must be changed at predetermined intervals (usually 10-14 days) to maintain efficient tooth movement	Simon et al., 2014
Types of aligners	- minor tooth movements with limited treatment objectives - direct to pts marketing/sales with minimal remote clinical supervision - in-house or laboratory fabrication with 3D printing, e.g. SureSmile, 3Shape, Spark - comprehensive treatment aligner options, e.g. Invisalign, ClearCorrect, Spark - <i>full arch aligners</i> with attachments, bite ramps, pressure ridges, elastic and button cut outs etc - <i>teen aligners</i> with block outs for partially erupted teeth and wear indicators - <i>mandibular advancement aligners</i> with advancement buccal block aimed to simulate TB appliance	Weir, 2017 Bowman, 2017
Factors influencing effect	- efficient tooth movements include: - anterior intrusion - posterior buccolingual inclination - upper molar bodily movements of about 1.5 mm - anterior alignment with proclination and/or IPR - less efficient tooth movements include: - anterior extrusion	Rosinni et al., 2015a Robertson et al., 2019 Robertson et al., 2019

	- anterior buccolingual inclination - incisor torque - rotation of rounded teeth - expansion by bodily tooth movement - Xtn space closure by bodily tooth movement - CI II correction	Ting et al., 2021 Zhou & Guo, 2020 Dai et al., 2019 Patterson et al., 2021
Advantages	• aesthetics - especially for adults • easier maintenance of oral hygiene and less severe white spot lesions compared to FA • ↓ periodontal health and soft tissue irritation • ↓ initial discomfort and better tolerated compared to FA • fewer clinical emergencies • control of unwanted tooth movements • good for minimal OB/AOB cases with posterior intrusion • ease of integration with remote monitoring and delegation of clinical care	Albhaisi et al., 2020 Rosinni et al., 2015b Miller et al., 2007 Buschang et al., 2013
Disadvantages	• orthodontic treatment with aligners is associated with worse treatment outcome compared to FA in adult pts • efficiency with limitation of certain tooth movements (anterior extrusion and Xtn cases) even with the use of specific attachments • inaccurate tooth movement predications often require overcorrections and frequent requirement for additional aligners (refinement) • compliance - 20+ hrs wear/day with frequent aligner changes (10-14 days) • cost and reliance on 3rd party laboratory/software • difficult with short clinical crown heights • allergies to thermoplastic materials	Papageorgiou et al., 2020 Lombardo et al., 2017 Krevitz et al., 2009; Robertson et al., 2020; Haouili et al., 2020 Allareddy et al., 2017
Recommended reading	Weir, 2017; Haouili et al., 2020	

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Arch Lengthening (Anteroposterior Expansion) and Lateral Expansion

Definitions	Arch lengthening (anteroposterior expansion) - ↑ the arch length using distal movement of posterior teeth or labial movement of incisors Arch expansion - management of 'narrow' arches by ↑ the upper or lower intercanine, interpremolar and/or intermolar width Arch depth - length of perpendicular line dropped from intermolar line (line drawn between widest point of molars) at level of mid-point of central incisors	
Arch width changes with age	• male arches wider than female • 6 weeks-2yrs: significant ↑ in the max and mand anterior and posterior arch widths in both male and female infants • 3-13yrs: significant ↑ in intercanine and intermolar widths in both arches • after the complete eruption of the permanent dentition, there was slight ↓ in dental arch widths, more in intercanine than in intermolar widths • lower intercanine width ↑ up to change to permanent dentition (no ↑ from age 12) • upper and lower intermolar width ↑ between 7-18yrs • little change in premolar width after 12yrs • arch width change may/may not be associated with change in arch length	Lee, 1999 Bishara et al., 1997
Indications for arch expansion	• correction of a unilateral crossbite • elimination of a displacement • relief of mild crowding (1mm ↑ in the inter-premolar width ↑ the arch perimeter by 0.7 mm) • avoiding creation of a crossbite in cases needing distal movement of upper buccal segments • preparation for a bone graft in a cleft alveolus • minimal crowding (1-2mm) • interceptive orthodontics (note: Little et al., 1990 showed this produces relapse in >80% of cases) • orthognathic or functional cases • has been suggested as treatment for resistance nocturnal enuresis but more research was suggested • correction of tipped teeth (often due to dento-alveolar compensation) - WALA line is the most prominent point on soft tissue ridge immediately occlusal to mucogingival junction; a line around the arch connecting these points on a model → useful representation of individual's dental archform	Adkins et al., 1990 Bell & LeCompte, 1981 Shaw & Semb, 1990 Little et al., 1990 Bazargani et al., 2016 Ronay et al., 2008
Indications for possible arch lengthening	• non-Xtn cases with only very mild crowding (1-2mm) • any change in archform is likely to relapse so lengthening must be kept to a minimum • ½ unit CI II molar relationship in non-Xtn case • regain space lost through early loss of primary teeth correction of: - incisal relationship in CI III case by proclination of <u>21/12</u> - retroclined mand incisors in CI II div 2 - CI II div 1 cases with mand incisors trapped in palate	Felton et al., 1987 Little et al., 1990
Clinical points of arch lengthening/ anteroposterior expansion	• "rule of thumb": 1mm of labial movement provides sufficient space for relief of 2mm of crowding (1mm on each side of arch so more space is often required) • labial movement more effective than lateral expansion at providing space • AP expansion may permit more effective lateral expansion	Steyn et al., 1996 Noroozi et al., 2002 Noroozi et al., 2002

Clinical points of lateral expansion	• expansion where posterior teeth were previously tipped lingually may be expected to be stable • stable expansion of lower intercanine width unlikely unless canines lingually displaced • ↑ stability of premolar expansion than canine expansion • expansion more likely to be stable in absence of Xtns • correction of bilateral crossbites is controversial, consider accepting untreated if there is no displacement; decision will depend on pretreatment inclination of teeth and presence of any underlying max transverse deficiency • over-expansion is advisable (palatal cusps of maxillary teeth should occlude on the lingual inclines of the buccal cusps of the mandibular molars) in anticipation of some relapse • ↑ in intermolar width produces linear ↓ in arch depth (often seen as ↓ in OJ) • 1mm of arch expansion causes 0.3mm ↓ in arch depth which equates to 0.6mm space creation in arch perimeter • claims that expansion improves nasal respiration remains equivocal • long-term Sk ↑ is 25% of long-term overall change	Lee, 1999 Lee, 1999 Lee, 1999 Proffit et al., 2012 O'Higgins & Lee, 2000 O'Higgins & Lee, 2000 Warren et al., 1987 Lagravere et al., 2005
Relapse	• up to 40% relapse has been found with all forms of active expansion • occurs via lingual tipping of molars • relapse less with fixed retainer than URA	Haas, 1980; Herold, 1989 Haas, 1980
Complications	• over expansion can cause scissorsbite • possible periodontal damage (equivocal evidence) • maxillary expansion with quadhelix in 9yr olds thins bone buccally to teeth • ↑ in MMP angle and lower face height → worsening AOB	Odenrick et al., 1991 Corbridge et al., 2011 Orton, 1990
Appliances used	also see sections on Appliances	Brierley & Sandler, 2017
URA	e.g. En Masse plate, expansion plate • relies on pt to turn expansion screw 1-2 ¼ turns/week • needs adequate seating and retention to produce expansion as the main effect is tipping • coffin springs are less well tolerated, retained and can be difficult to adjust but can provide differential expansion laterally and AP • ELSA (expansion and labial segment alignment appliance), expands posteriorly, palatal arms align incisors	Bell & LeCompte, 1981
Expansion arch	• prospective RCT of quadhelix versus buccal arch expansion - both were equally effective at crossbite correction however expansion arch is cheaper • both appliances were uncomfortable • 25% pts disliked appearance of quadhelix and 75% the expansion arch	McNally et al., 2005
Quadhelix	• can be fixed or removable • may be pre-fabricated or laboratory constructed • usually made from 0.9mm SS • bi-helix used in mand arch to aid correction of severe scissorsbite or in cases of gross narrowing or distortion • some differential expansion of intermolar width possible (NB: changes in pt's original archform may not be stable) • activated by ½ a tooth's width on either side producing a desirable force level of 300-400g • works by combination of buccal tipping and skeletal expansion in a ratio of 6:1	Boysen et al., 1992 Felton et al., 1987 Brierley & Sandler, 2017 Gill et al., 2004

	• preferred method of expansion in mixed dentition • may achieve 1.5mm more molar expansion than expansion plate • may be 20% more likely to correct crossbites than removable expansion plates in children aged 8-10yrs (see section on Early Correction of Crossbites)	Agostino et al., 2014 Agostino et al., 2014 Agostino et al., 2014
Fixed appliances with no mid palatal expansion	• limited amount of expansion possible with FA alone • requires rectangular wire to ↓ unfavourable dental tipping • no difference in maxillary arch dimensional or inclination changes during alignment between self-ligating or conventional brackets • unilateral expansion possible but requires careful placement of buccal root torque on other "non-treated" side to prevent unwanted tipping • X-elastics can be used to lingual or palatal attachments such as buttons or cleats	Fleming et al., 2013
Rapid Maxillary Expander (RME)	• see section on Correction of Skeletal Maxillary Transverse Arch Deficiency	
Surgically Assisted RME	• see section on Correction of Skeletal Maxillary Transverse Arch Deficiency	
Quad/Tri-Helix	• see section on Correction of Skeletal Maxillary Transverse Arch Deficiency	
Functional appliances	• produce active expansion (usually with either expansion screw or palatal arch) to prevent crossbite formation whilst a CI I molar relationship is being obtained • Fränkel appliance produces passive expansion only by removing influence of buccal tissues with buccal shields	
Treatment objectives and methods	Distalisation of upper buccal segments • HG with URA (palatal finger springs to upper 6s, bite plane, HG to 6s tubes) 'Nudger' • HG with no URA - HG to 6s tubes only may take longer as there are no URA finger springs to prevent relapse during the day when HG is not worn • distalising superelastic NiTi coil springs • magnets supported with CI II traction • active palatal arch Distalisation of lower buccal segments • lip bumper - not well tolerated, tend to procline LLS • removable appliance and HG Proclination of upper or lower incisors • URA (split screw anteriorly, 'Z' springs, or 'T' springs) • ELSA (recurved spring or 'wiper' arms to procline incisors) • labial crown torque (rectangular wire in FA) • avoiding the use of 'lacebacks' in CI III maxillary incisors • side effect of some functional appliances is to procline the mand incisors if there is no incisal capping	Cetlin & Ten Hoeve, 1983 Bondemark et al., 1994 Gianelly et al., 1989 Cetlin & Ten Hoeve, 1983 Cetlin & Ten Hoeve, 1983 Orton et al., 1983
Complications and problems	See sections on Headgear and Stability	
Recommended reading	Gill et al., 2004; Agostino et al., 2014; Brierley & Sandler, 2017	

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Correction of Skeletal Maxillary Transverse Arch Deficiency

Definition of Maxillary Arch Deficiency	- absolute due to a wide mandible and/or a narrow maxilla - relative or apparent, due to position of the teeth relative to the basal bone	
Incidence	8-18% of referred pts have maxillary transverse deficiency	Gill et al., 2004
Aetiology	Multifactorial: - developmental - habit (e.g. prolonged thumb sucking habit) - iatrogenic (e.g surgical correction of cleft)	
Clinical signs	- unilateral or bilateral crossbite with or without a functional jaw shift (displacement) - crowded, rotated and palatally or buccally displaced teeth - narrow tapering maxillary arch form - high palatal vault - excessive buccal corridors	
Diagnosis	- check for jaw shift (displacement) with pt closing from RCP to ICP; if there is no displacement it is more likely to be skeletal rather than dental - only visible radiographically using a PA cephalogram (used by Ricketts but found poor reproducibility of measurements) or CBCT - can also measure on casts and compare with a template	Moyers et al., 1976
Relevant age related changes	- arch width change may/may not be associated with change in arch length - mid-palatal suture closure can be expected at around 15yrs, expansion once closed can lead to alveolar bending, lateral tooth displacement, tooth extrusion and transverse relapse	Cureton & Cuenin, 1999
Indications for arch expansion	- correction of a unilateral crossbite - elimination of a displacement - avoiding creation of a crossbite in cases needing distal movement of upper buccal segments 'V' shaped arch, e.g. in a 'thumb-sucker' - preparation for a bone graft in a cleft alveolus - child with <31mm of intermolar width at age 7yrs is unlikely to attain adequate arch dimensions through normal growth alone - orthognathic cases to enable arch co-ordination	Bell & LeCompte, 1981 McNamara & Brudon, 1983 Shaw & Semb, 1990 Howe et al., 1983
Complications	- over expansion can cause scissorsbite - possible periodontal damage (equivocal evidence) ↑ in MMP angle and lower face height thus worsening AOB	Odenrick et al., 1991 Orton, 1990
Appliances used	Rapid Maxillary Expander (RME) - pt turns a 'Hyrax' screw once a day (0.2-0.5mm/day) for 1-3 weeks (midline diastema develops quickly) - soldered bar connecting bands to screw must contact upper premolars (tooth borne) - may produce more bodily movement of teeth than other appliances 40% of the expansion may be due to skeletal change - ratio between anterior and posterior expansion is 2:1 - posterior max expands less due to zygomatic buttress - evidence that the mid-palatal suture does split producing maxillary expansion - can be used with early facemask to correct CI III	Herold, 1989 Bell, 1982 Bell, 1982 Wertz, 1970 Gill et al., 2004 Vaughn et al., 2005

	• RME does not result in meaningful change in airway dimensions • tooth-bone-borne RME → ↑ Sk expansion than tooth-borne RME although only 1mm more <i>Limitations</i> • amount of available bone for expansion • controversial evidence: ↑ periodontal breakdown compares with just using URA or FA • risk of nasal septum deviation if used in primary dentition • upper age limit for using RME due to ↑ resistance to maxillary base expansion with needs prolonged retention • some say can use on pts >15yrs • bonded acrylic RME with occlusal coverage designed to ↓ tipping and extrusion of molars: no significant differences between bonded and banded RME found • molar crown tipping found to be significant with Hyrax <i>Stability</i> • significantly more favourable short term and long term Sk changes found when used pre-puberty • long term transverse Sk maxillary ↑ is approx. 25% of the total dental expansion in pre-pubertal adolescents Surgically Assisted RME (SARME or SARPE) • used to overcome expansion problems in non-growing pts • use buccal corticotomy or Le Fort I osteotomy and/or mid palatal splits in conjunction with Hyrax screw <i>Claims</i> • less periodontal support loss - unsubstantiated • ↑ in nasal air flow - unsubstantiated <i>Evidence</i> • surgical and non-surgical techniques: no significant difference in stability of expansion after 1yr • non-surgical RME allows sufficient expansion in adults <i>Stability</i> • follow up of 6.4yrs found crossbite correction is stable • ↓ in transverse dimension is most pronounced 3yrs post-treatment • study of 30 consecutive pts following SARPE, 15 of whom had 6mths of TPA, 15 of whom had no retention, showed no difference in amount of relapse <i>Problems</i> • surgical procedure associated with morbidity and risks, e.g. haemorrhage, infection, hospitalisation • risk of nasal septum deviation Micro-implant Assisted RPE (MARPE) • bone-borne expanders • used in older pts • localise lateral forces to mid-palatal suture and minimise tooth movements from tooth-borne RME Quad/Tri-Helix • may be pre-fabricated or laboratory constructed usually from 0.9mm SS • can be fixed or removable • tri-helix useful in cleft cases • some differential expansion of intermolar width possible (NB: changes in pt's original archform may not be stable) • activated by ½ a tooth's width on either side • works by combination of buccal tipping and skeletal expansion in a ratio of 6:1	Cheung et al., 2021 Bazargani et al., 2021 Greenbaum & Zachrisson, 1982 Bell, 1982 Wertz, 1970; Bishara & Staley, 1987 Reed et al., 1999 Oliveira et al., 2004 Baccetti et al., 2001 Lagravere et al, 2005 Warren et al., 1987 Berger et al., 1998 Handelman, 1997 Magnusson et al., 2009 Prado et al., 2014 Carlson et al., 2016 Boysen et al., 1992 Felton et al., 1987 Gill et al., 2004
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	<i>Advantages</i> • provides some differential expansion • can derotate molars • do not rely on pt co-operation for wear • good retention • incorporate FA • more cost effective compared to URA <i>Disadvantages</i> • molar tipping • limited skeletal change • may produce less dental tipping than a URA but the findings are inconsistent <i>Evidence</i> • RCT of 4 groups, URA, onlay expansion, quad and control; all pts in quad group had crossbite correction however ⅓ of pts in URA group had incomplete crossbite correction due to poor co-operation with URA <i>Stability</i> • 3yr follow up of the URA and quad group found that crossbite correction was maintained but mean maxillary widths never reached the same dimension as controls	Herold, 1989 Petrén et al., 2011 McNally et al., 2005 Petrén & Bondermark, 2008 Petrén et al., 2011
Recommended reading	Gill et al., 2004; Zuccati et al., 2013	

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Adult Orthodontics

Need	6% of adults have OJ ≥ 7mm 9% have OB complete to palate 56% at least 1 upper tooth out of alignment 69% at least one lower tooth out of alignment	Todd & Lader, 1988
Demand	- demand appears to be $\uparrow$ - adult pts consist of 23% of pts in USA practice 14% of Dutch adults expressed interest in treatment	Cedro et al., 2010 Keim et al., 2013 Burgermodjik et al., 1991
Reasons for increasing demand	- improved dental services $\uparrow$ dental awareness - better social acceptance - expansion of appliance technology, with availability of aesthetic appliances - more financially and mentally prepared for treatment - dissatisfaction with previous ortho treatment	
Features	25% are re-treatment cases, mainly CI II/2 types - may present due to splaying of teeth from perio disease >70% are female - more CI III cases than in the general population - up to 50% have unstable or neurotic personality traits	Khan & Horrocks, 1991 Salonen et al., 1992 McKiernan et al., 1992
Motivation	- improvement of aesthetics - relief of TMD - improvement of function - usually excellent motivation	Breece & Nieberg, 1986 Andreason, 1972
Treatment considerations	General - may feature heavily restored, root treated, periodontally involved teeth $\uparrow$ dental and occlusal awareness - adults more likely to have a relevant medical history - treatment often involves other disciplines - may accept limited treatment goals once valid consenting procedures undertaken - previous ortho tx Psychological - adults may have high expectations - may hide true motives for treatment - treatment had negative impact on quality of life indicators however these returned to pre-treatment level within 3mths; significant improvement in self-esteem noted post-treatment Adjunct to restorative work - uprighting abutment teeth - redistribution or closure of spaces - intrusion of over-erupted teeth - extrusion of fractured teeth Periodontal - all pts should have BPE at assessment and treat active disease before orthodontic treatment, otherwise loss of attachment may be accelerated - monitor periodontal health throughout treatment; best indicator of active disease: persistent bleeding on probing - use light forces - remove excess adhesive from round brackets	Espeland & Stenvik, 1991 Bond, 1972 Noar et al., 2015 Christensen & Luther, 2015; Lew, 1993 Johal et al., 2015 Mitchell, 2007 Boyd et al., 1989; Christensen & Luther, 2015 Greer et al., 2018 Melson et al., 1988

	• use bonds not bands • minimise tooth extrusion - ↓ periodontal support and ↑ face height • to correct ↑ OB intrude anterior teeth rather than extrude posterior teeth for above reasons • teeth are more prone to tipping than to bodily movement • plaque retentive is less with steel ligatures > self-ligating brackets > elastomeric ligatures • if previous periodontal disease monitor periodontal status every 3mths throughout treatment • treatment may result in 'dark triangles' • significant correlation between incidence and severity of recession with excessive proclination (>10°) of lower incisors • gummy smile in adults can demand orthognathic surgery including Le Fort I osteotomy and maxillary impaction • in non-compromised dentitions adults are not inherently more likely than adolescents to loose alveolar bone or root length • ↑ popularity of adult orthodontics → ↑ numbers of pts with periodontal disease seeking treatment; careful interdisciplinary approach should be considered Rate of tooth movement • delayed initial tissue reaction due to ↓ cellular activity in adults • adult bone less reactive to mechanical forces than adolescent • subsequently similar rate of tooth movement in adults and adolescents • ↑ in co-operation compensate for delay initial tooth movement Lack of growth • growth modification not possible, i.e functional appliances • mid-palatal suture is closed • need to ↓ OB with intrusion mechanics, e.g. utility arches • Sk discrepancies only treated with orthodontic camouflage or orthognathic surgery Aesthetic and restorative • may prefer ceramic brackets, lingual orthodontics or clear aligners • Xtn pattern may be modified by tooth quality • can 'debulk' amalgams to provide space • beware of damaging heavily restored teeth • adapt bonding procedures for restored teeth, e.g. gold and porcelain surfaces by sandblasting with 50µm aluminium oxide or porcelain by etching with 9.6% hydrofluoric acid TMJ • assess for TMD at start of treatment • careful of pts requesting treatment to improve TMD Anchorage • reluctance of adults to wear HG • miniscrews/palatal arches as alternative • precise mechanics needed • use of restorative implants if missing teeth or ↓ periodontal support • Sk anchorage devices serve as anchorage units are used especially when the teeth present are compromised • ↑ tendency for teeth to tip excessively	Williams et al., 1982 Forsberg et al., 1991; Garcez et al., 2011 Sanders, 1999 Artun & Krogstad, 1987 Sarver & Weissman, 1991 Harris & Barker, 1990 Gkantidis et al., 2010 Reitan, 1954 Chiappone, 1976; Boyd et al., 1989 Liskova & Hert, 1971; Bond, 1972 Houston, 1988 Ghafari, 1992 Zachrisson & Buyuykilmaz, 1993 Christensen & Luther, 2015 Dyer et al., 1991 Ong et al., 1998 Leung et al., 2008
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	Closure of old Xtn spaces - reshaping of cortical bone required - slow and difficult - old Xtn space - useful alternative to premolar Xtn for relief of anterior crowding - necking in the missing teeth site, hinder tooth movement - maintaining space closure can be difficult, need careful detailing to achieve root parallelism Stability - adult occlusion as stable as adolescent with respect to molar relationship - permanent retention if ↓ periodontal support Treatment times - good cooperation makes up for slower initial tooth movement - treatment times are similar ↑ failure rates	Hom & Turley, 1984 Harris et al., 1994 Kahl-Nieke, 1996 Dyer et al., 1991
Recommended reading	Scott et al., 2007; Christensen & Luther, 2015	

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Orthognathic Surgery

Definition	Correction of functional and aesthetic consequences of severe dentofacial deformity through combination of orthodontic, surgical and possibly, restorative dentistry	
Aims of treatment	- to achieve optimal dental and facial aesthetics for pt and stable occlusal and Sk result with normal occlusion - to optimise future oral health - to eliminate symptoms of dentofacial deformity - to minimise treatment morbidity - a satisfied pt	
History	- surgery for mandibular prognathism began in late 1800s - procedures progressed with introduction of the mandibular bilateral sagittal split osteotomy (BSSO) in 1957 - Le Fort I osteotomy introduced in 1975 - surgically assisted rapid maxillary expansion (SARPE) and segmental maxillary surgical expansion - use of distraction osteogenesis in 1994 - some now advocating surgery before orthodontic treatment (surgery 1st) - TMJ replacement surgery for non-functioning TMJ in 1997	Angle, 1898 Trauner & Obwegeser, 1957 Bell, 1975; Epker & Wolford, 1975 Suri & Taneja, 2008 McCarthy, 1994 Sugawara et al., 2010 Speculand, 2009
Types of cases	- severe Sk CI 3 - severe Sk CI 2 - long face syndrome/AOB - facial asymmetries - chin abnormalities - craniofacial anomalies, e.g. CLP	
Treatment Need	- pts seek treatment for a variety of reasons including function, aesthetics and psycho-social well being - Index of Orthognathic Functional Treatment Need (IOFTN) - developed to assist prioritization of severe malocclusions not amenable to orthodontic treatment alone - evolution of IOTN for orthognathic cases - shown to be reliable	Cunningham & Johal, 2015 Ireland et al., 2014 James et al., 2015
Timing of treatment	Pre-pubertal growth <i>Sk CI 2 mandibular advancement cases and surgery for vertical excess</i> - rarely undertaken, although mandibular growth continues it is mainly in vertical direction <i>other surgical procedures</i> - rib grafts in craniofacial microsomia cases; freeing of TMJ in ankylosis of condyle Post-pubertal growth - most surgery undertaken when growth has slowed, more important in Sk CI 3 cases - more scope for growth modification and dental camouflage in Sk CI 2 cases - most surgery performed once pre-surgical orthodontics complete - some recommend surgery prior to orthodontic completion	Washburn et al., 1982; Snow et al., 1991 Lee, 1994
Assessment	Pt factors <i>age and sex</i> - influences amount of growth remaining <i>race</i> - influences profile considerations <i>medical history</i> - may contraindicate surgery <i>psychological</i> - pt perception of their problem and reasons for treatment must be considered and understood <i>obstructive sleep apnoea</i> - sleep clinic referral	Kiyak et al., 1982; Wilmot et al., 1993; Oluwajana, 2015 Islam et al., 2014

	• <i>body dysmorphic disorder</i> - 3 conditions must be satisfied: 1. preoccupation with a defect in appearance 2. defect is imagined or is minor and pt's concern excessive 3. preoccupation not explained by other psychiatric disease - remain unhappy at end of treatment - should be referred for counselling/behaviour therapy Clinical factors Important to assess Sk, soft tissue and dental features • <i>Extra-oral features</i> Frontal: - symmetry - vertical proportions - divide face into $\frac{1}{3}$ - midline in relation to max, mand, nose, chin point - lip line • at rest 2-4mm of incisor show • smiling and exposure of upper gingival, >2mm exposure at rest considered unattractive - zygomatic prominence - interpupillary distance (65mm) - intercanthal distance (34mm) - alar base width Lateral: - AP relationships - vertical proportions - AFH and PFH - profile <i>zero median</i> (perpendicular from nasion through Frankfort plane), chin point should be $\pm 0-2\text{mm}$ - soft tissue assessment <i>E-line</i> (nasal tip to chin point) ideally lips on this line <i>harmony line</i> (line from soft tissue chin point through upper lip) ideally should bisect nose <i>nasolabial angle</i> (desirable range: $85^\circ-105^\circ$) • <i>TMJ</i>: limitation of opening, noises, pain • <i>Intra-oral features</i> arch relationships - centrelines/crossbites/crowding tooth angulations - dental compensation for Sk pattern Study Models • hand held/articulated • arch relationships can be visualised Imaging • R/G (lateral cephalometric, DPT, $\pm$ postero-anterior views, $\pm$ individual periapical/bitewing) - to locate caries, unerupted teeth, other pathology • $\pm$ bone scan (technicium) • photographs • video-imaging • CBCT/CT scans - can allow 3D printing of boney/dental structures and virtual surgical planning (VSP)	Cunningham et al., 1996a Proffit & White, 1991 Gibson & Noar, 2019 Hunt & Rudge, 1984 Ricketts et al., 1979 Holdaway, 1983 Arnett & Bergman, 1993 Sarver et al., 1988 Chen et al., 2021
Stages of joint management	1. Initial presentation • multidisciplinary team approach - surgeon, orthodontist, restorative dentist, $\pm$ psychologist 2. Initial planning • establish where problem lies, i.e. max, mand, both • planning can be undertaken using i) <i>cephalometric analysis</i> - computer assisted - hand tracing ii) <i>model surgery</i>	Proffit & Epker, 1980; Harradine & Birnie, 1985 Henderson, 1974

	iii) <i>photographic</i> iv) <i>video-imaging</i> v) <i>computer imaging</i> - relate hard tissue changes to changes in soft tissue profile using algorithms - much variability in soft tissue prediction - using computer imaging improves pt perception of outcome • max AP position evaluated by viewing position in relation to nasion perpendicular, max should lie on or just in front • if bimaxillary procedure necessary plan max first as mand autorotates upwards and forwards after movement • not necessary to always correct to normal values as treating pt • hard tissue movement is in ratio 1:1 • soft tissue movement variable ratios, structures further away from basal bone move less 3. Preliminary surgery e.g. removal of 8's 4. Presurgical orthodontics (9-18mths) • aims: - ideal tooth position in relation to dental bases - ideal alignment to allow good interdigitation post-surgery - correct torque - expansion to allow co-ordination of arches post-surgery 5. Final planning • must be exact with tracings, articulated models • aim for CI I canines as incisors can be tipped • 3-point contact sometimes used in deep-bite cases, i.e. occlusal contact at incisors and molars, post-op extrude premolars to level arch and flatten Curve of Spee 6. Surgery • surgical wafers constructed - 1 for single arch surgery, 2 for bimaxillary procedures 7. Postsurgical orthodontics • detailing occlusion • approximately 7½mths 8. Retention 9. Review	Sarver et al., 1988 Philips et al., 1995 McNamara, 1983 Hunt & Rudge, 1984 Luther et al., 2007
Borderline camouflage vs surgery cases	Questions to ask • is pt growing? • is there enough space from Xtn to align teeth and camouflage Sk pattern? Good camouflage results • needs normal soft tissue morphology • normal/short-faced • no transverse Sk problems • mild Sk discrepancies • minimal crowding <4-6mm Poor camouflage results • asymmetries • poor soft tissue morphology/profile • long-face pts, ↑ vertical proportions • AOB • moderate-severe AP discrepancies: rule of thumb: $9^\circ > ANB > -4^\circ$ • moderate-severe crowding >4-6mm • OJ >10mm in non-growing pt, Po-zero meridian line is >18mm, Go-Po <70mm, total face height >125mm	Proffit et al., 2012 Ackerman & Proffit, 1997 Kerr et al., 1992 Proffit et al., 1992

Role of orthodontics	- to enable achievement of optimal facial form and aesthetics and maximise surgical correction - to assist post-operative surgical stability for providing good occlusal fit - to provide - best means of intra-operative intermaxillary fixation - means of attachment of post-op intermaxillary elastics; often CI II/III or vertical box elastics are necessary	
Tooth movement required	relief of crowding - Xtns may be necessary, often different Xtns to one chosen for orthodontic camouflage; avoid Xtns in lower arch in Sk CI 3 cases if possible as can make decompensation of the lower arch difficult alignment and levelling - extrusion best achieved post-surgery whereas intrusion best achieved pre-surgery; can treat to 3-point contact decompensation - to allow max surgical movements; Xtns may be necessary to provide space; ↑ stability when proclining lower incisors in surgical CI 3 cases arch co-ordination - allow for proposed surgical move centreline correction space closure ± space creation for surgical cuts post-operative settling of the occlusion localisation of space for restorative measures	Jacobs & Sinclair, 1983 Artun et al., 1990
Surgical techniques	Mandible, in general can achieve ± 1cm movement, mainly used to correct Sk CI 2/3 problems (also see section on Distraction Osteogenesis) Procedures - condyle - condylar shave for developmental growth disorders (Condylar hyperplasia)/total joint replacements for non-functioning joints (ankylosis/severe osteoarthritis) - segmental - Kole osteotomy - body osteotomy (rarely used) - ramus - bilateral sagittal split osteotomy (BSSO) vertical subsigmoid osteotomy (VSS) C-shaped and inverted L osteotomy (rarely used) ± grafts - genioplasty - augmentation, reduction, asymmetries Maxilla, in general can achieve + 1cm movement, mainly used to correct maxillary excesses and AOB Procedures - segmental - Wassmund/Wunderer (anterior) Schuchardt (posterior) - Le Fort I osteotomy - Le Fort II osteotomy - Le Fort III osteotomy - ± Kufner modification, does not alter position of nose	Dimitroulis, 2018
Problems	Surgical - morbidity of surgical procedure 20-25% risk of perm altered sensation with BSSO ↑ alar width and fullness of upper lip with maxillary impaction - double chin with mandibular set backs - lip sag following augmentation genioplasty - ID nerve damage - idiopathic condylar resorption Orthodontic - all associated risks of orthodontic treatment (see sections on Intra-oral and Extra-oral Iatrogenic Damage)	Tucker et al., 1991 Edler, 1990 Ow & Cheung, 2009

	- problems with closure of old Xtn spaces, root resorption, inadequate expansion - risk of periodontal recession particularly around lower incisors in CI 3 cases after decompensation Relapse - variable depending on procedure ↑ risk when mandibular procedures are used to close AOB due to stretching of pterygo-masseteric sling - idiopathic condylar resorption leading to AOB	Edler, 1990 Fish & Epker, 1986
Cost of Orthognathic treatment	- relatively inexpensive surgical care pathway - cost vary between units, influenced by type of surgery and length of in-pt stay - orthodontic cost amount to approx 25% of total cost	Kumar et al., 2008
Stability	- relapse: linear, rotational or both - late relapse >1yr post op in 2.5-8% of pts, depends on direction of movement, fixation, technique used - similar relapse with BSSO and VSS, approximately 10%, but VSS relapse is in posterior direction whereas BSSO is in anterior direction - maxillary intrusion with Le Fort I show good stability - maxillary extrusion with Le Fort I has 20% relapse but both grafting and undertaking bimaxillary procedure improves stability - Proffit produced a hierarchy of stability: i. maxillary inferior movement - unstable ii. mandibular advancement - stable if no vert face height change iii. mandibular setback - unstable iv. transverse expansion of max - very unstable	Proffit et al., 2007 Proffit et al., 1996 Proffit et al., 1991a Proffit et al., 1987 Proffit et al., 1991b Wardrop & Wolford, 1989; Proffit et al., 1991c Proffit et al., 2007
Outcome	- occlusal outcome: 83% ↓ in PAR, no difference between orthodontics + surgery, and orthodontics only pts - psychological benefit demonstrated - perception of outcome: 92-100% pts satisfied with results 16yrs follow-up - still high satisfaction level	Baker et al., 1999 Hunt et al., 2001 Flanary et al., 1985 Cunningham et al., 1996b
Recommended reading	General - Proffit & White, 1991, Cunningham & Johal, 2015 Prediction - Harradine & Birnie, 1985 Psychological - Hunt et al., 2001; Oluwajana, 2015 Relapse - Fish & Epker, 1986; Edler, 1990 Stability - Proffit et al., 1991a-c; Proffit et al., 2007	

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Distraction Osteogenesis

Definition	Inducing a bone callus by osteotomy or corticotomy followed by distraction of proximal and distal ends resulting in ↑ of bone length	Davies & Sandy, 1998
History	- orthodontic tooth movement and rapid maxillary expansion uses mechanical force to induce new bone 1905 bone lengthening by complete osteotomy and distraction described by Codvilla - Ilizarov first to define biological basis and practical use in limb lengthening by corticotomy only - developments of distraction osteogenesis to maxillofacial and craniofacial problems - becoming more mainstream in correction of craniofacial anomalies and where large Sk movements are required	Barber et al., 2018a Ilizarov, 1988 McCarthy et al., 1992 Grayson & Santiago, 1999
Types of distractors	- intraoral, e.g. The Intraoral Distractor - extraoral, e.g. Rigid External Distractor (RED)	Barber et al., 2018b
Indications	Correction of congenital craniofacial defects - micrognathia (up to 24mm elongation reported) - unilateral (e.g. hemifacial microsomia), bilateral (e.g. Pierre Robin Sequence) including neonatal distraction for severe airway obstruction - mid face retrusion, e.g. CP/syndromic craniosynostosis - intact arch distraction or segmented options, e.g. anterior maxillary segmental distraction (AMSD) - calvarial expansion in craniosynostosis Correction of other craniofacial defects - infection - trauma - cancer Mandibular symphyseal distraction Bone augmentation prior to implants	Resnick & Padwa, 2019 Breik et al., 2016 Saltaji et al., 2014 Tahmasbi et al., 2018 Alkan, 2007
Protocol	- corticotomy or osteotomy 7-10 day latency period for callus formation - intact vascular supply - prolonged, progressive and gradual distraction at a rate of 1mm/day - correct rate and rhythm of distraction: - below 0.5mm/day → premature union - above 1.5mm/day → non-union - consolidation period of 3mths	Barber et al., 2018b
Magnitude of advancement	age and gender have no effect on the ratio of hard:soft tissue horizontal advancement	Melugin et al., 2006
Potential advantages	- used at an earlier age than orthognathic surgery - possibly improves soft tissue functional matrix during growth - no objective studies confirm this ↓ number of operations ↓ need for bone grafts - magnitude of movements ↑ than conventional surgery - possibly less relapse - no long term studies >5yrs	Moss & Salentijn, 1969 Marquez et al., 2000
Disadvantages	- recent technique, frequent complications reported - movement limited by distraction device with multi-directional force vectors difficult to control 2 operations required: one to place, one to remove Complications - neurosensory dysfunction - direct or traction injury - pain - deformation/migration of pins through bone	Nørholt et al., 2011

	• infection • incomplete osteotomy • trismus - distraction device may interfere with TMJ function as it passes below zygomatic arch • teeth damaged by screws, pins and bone cuts • skin scarring by transcutaneous pins if used	
Recommended Reading	Barber et al., 2018a,b; Resnick et al., 2019	

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Relapse and Retention

Archform

Retention

Relapse and Stability

Archform[illegible]

	- the soft and hard tissue limitations - the biological differences between the pts	
Summary	• there is no generalised archform that is applicable to an individual • review of various archforms found no particular archform was the closest match for more than 20% of cases • archform should be tailored to the original arch shape of an individual • prefabricated archform useful in gaining closest fit for majority, but individual adjustment is necessary • significant arch form change in early treatment even with undersized NiTi wires • although clinicians may aim to maintain pre-treatment archform, this is often not the case in clinical practice	Felton et al., 1987 Felton et al., 1987 Little, 1990 De la Cruz et al., 1995 Fleming et al., 2014 McNamara et al., 2010
Studies on relapse in archform	• 65% of cases had a change in archform, over two thirds returned to their pre-treatment shape • meta-analysis of 26 longitudinal studies: the mandibular intercanine width tended to expand during treatment and contract post-retention to approximately the original dimension • greater the change in archform during treatment is associated with greater post-retention change • large individual variation in the stability of archform post-treatment • pre-treatment archforms appear to be the best guide to future stability • some expansion in the upper premolar region may remain stable long term	Felton et al., 1987 Burke et al., 1998 De la Cruz et al., 1995 Little, 1990 Sadowsky et al., 1994, BeGole, et al., 1998
Recommended reading	Lee, 1999; Fleming et al., 2008a,b	

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Retention

Definition	holding of teeth following orthodontic treatment in treated position for period of time necessary for maintenance of the result	Moyers, 1973
Why is this needed?	- for reorganisation of the periodontal and gingival tissues - PDL reorganises over 3mths - gingival (collagenous fibres) reorganise over 6mths - gingival (supercrestal fibres) reorganise over 1yr	Reitan, 1967
Principles of retention	- teeth relapse in the direction of their original tooth position due to elastic recoil of PDL fibres - masticatory stimulation of PDL promotes fibre reorganisation (remove retainers for eating and avoid over-rigid bonded retainers) - retain for more than 1yr, retainers can be worn part time - retain if possible until growth has reached adult levels in order to minimise relapse	Sadowsky & Sakols, 1982
Planning retention	Consider the presenting malocclusion: - rotations - ? circumferential supracrestal fiberotomy and interproximal enamel reduction (see section on Relapse) - diastemas - ? fraenectomy (see section on Relapse) - deep OBs, e.g. ? incorporate a bite plane - Sk discrepancies, consider 'active' retention, e.g. 'high pull' HG and bite blocks for an AOB case, HG throughout growth for severe Sk CI 2 cases, active retainers with postured bite for post-functional cases - required archform changes, e.g. proclination of LLS (see section on Relapse) - retention should be planned during treatment planning	Boese, 1980; Edwards, 1988 Pinson & Strahan, 1974 Kaplan, 1988 Nanda & Nanda, 1992 Fleming, 2021
Cases requiring no retention	- corrected anterior crossbites where there is adequate OB - posterior crossbites with good interdigitation, adequate buccal OB and minimal buccal tipping of teeth - cases relying on spontaneous alignment following Xtns ("driftodontics") - these cases are all still susceptible to natural age changes, e.g. late lower incisor crowding	Kaplan, 1988
Cases requiring permanent/semi-permanent retention	- expansion cases - spaced cases - multiple or severely rotated cases - periodontal cases - anteroposterior change >2mm of LLS - alignment of palatally displaced maxillary lateral incisors in the absence of positive OB at the end of treatment - correction of ↑ OJ with lip incompetence at treatment end	Kaplan, 1988 Proffit, 1990
Bonded retainers	- bond failures occurred mainly during the first year (33%) compared to the second year (7%) - no difference in the risks of failure between mandibular retainers bonded with direct and indirect methods - fewer unexpected posttreatment changes with retainers bonded with the indirect compared with the direct method 90.5% of pts with mandibular 3-3 bonded retainers at 5yrs maintained alignment; 9.5% had average 0.81mm ↑ in irregularity, highly correlated with retainer bond failure - no significant difference in relapse in the LLS between fixed and removable retainers; recent evidence suggests fixed retainers are more effective than removables in maintaining LLS alignment however there was a high drop-out rate in the study	Egli et al., 2017 Renkema et al., 2011 Atack et al., 2007 Al-Moghrabi et al., 2018

	• 46.4% failure rate of mandibular 3-3 bonded retainers found in a 2yr follow-up; no difference between chemical or light cure in failure rate • 5yr follow up, mandibular 3-3 (bonded only to canines) retainers were effective in preventing relapse in 60% of pts, however 40% had ↑ in incisor irregularity • approximately 23% failure rate over 3yrs (plaque and calculus scores higher at debond than 3yrs) • multistrand wire → more incisor control than round wire • 45/60 pts (75%) still had bonded mandibular 3-3 retainers in situ after 20-29yr; no associated perio disease/caries • can hinder interdental cleaning and carries the risk of caries under partially failed bonding material • can lead to unwanted labial movement or torque of lower anterior teeth if partial failure • failure rate 12-50%; most commonly between 2 and 3 • large interoperator variability in failure rates • bonded retainers better at maintaining alignment in first 6mths after debond than vacuum formed retainers (VFRs) but at 18mths no difference • no difference in max relapse with bonded or VFR, but bonded more effective in maintaining alignment in lower but had ↑ failure rate over 1yr • bonded retainers more comfortable, ↓ interfere with speech, ↓ compliance to wear but harder to keep clean • ↑ accumulation of plaque and calculus than VFRs; minimally worse gingival inflammation than VFRs, but no clinically significant, adverse periodontal health problems • systematic review on effects of fixed orthodontic retainers on periodontal health concluded: bonded retainers are a retention strategy compatible with periodontal health (not related to severe detrimental effects on the periodontium) • ↑ occlusal settling occurs in posterior segments in bonded retainer cases over time	Pandis et al., 2014 Renkema et al., 2008 Artun et al., 1997 Artun et al., 1997 Booth et al., 2008 Bearn, 1995 Katsaros et al., 2007 Iliadi et al., 2015 O'Rourke et al., 2016 Forde et al., 2017 Forde et al., 2017 Storey et al., 2018 Arn et al., 2020 Alkan & Kaya, 2020
Removable retainers	• 'Hawley' and VFRs most popular • 'Hawley' appliance: many design variations: acrylated labial bows to improve control of rotated teeth/soldering labial bow to 6 crib bridge to minimise space re-opening in Xtn sites, however no evidence to support this • allow superior vertical settling • wrap around 'Begg' type retainers are useful to allow vertical settling and interdigitation of buccal segments whilst maintaining arch relationships • 'Barrer' retainer useful to realign a relapsed LLS, requires re-setting teeth in wax on a model and constructing retainer to this set up • thermoplastic retainers (Essix and VFRs) - quick and easy to fabricate, usually part time wear: polyvinyl chloride 1.5mm sheets heated and vacuum or pressure formed over working casts • advantages: simple, quick, easy fabrication, cheap, requires little adjustment • may also act as carriers for bleaching agents and night guards for bruxism but can become cariogenic reservoir • ↑ wear with polypropylene VFR than polyethylene • 'Essix' retainer - cover incisors and canines only - disadvantage: some pts may develop AOB's • 'VFRs' - full coverage to stop 'overeruption' • VFRs are more cost effective than Hawleys	Sauget et al., 1997 Sheridan et al., 1993 Sheridan et al., 1995 Raja et al., 2013 Sheridan et al., 1993 Hichen et al., 2007

	• over a 6mth period VFRs were better than Hawleys (0.5mm ↓ contact point displacement 3-3) at maintaining correction of maxillary mandibular labial segments • no clear evidence of differences between Hawleys/VFRs • although initial compliance is ↑ in VFR, overall Hawley has better compliance after 2yrs post treatment • Hawley lasts longer but more difficult to wear for pts compared to VFR and bonded retainer	Rowland et al., 2007 Mai et al., 2014 Pratt et al., 2013 Littlewood et al., 2016
Retention duration and regimen	• beneficial to retain for 1yr; cases only retained for 6mths had double the amount of relapse (small sample!) • no difference between part-time versus full time wear of VFRs • no difference between part time versus full time wear of Hawley retainers • no optimal duration of retention and wide variations in retention protocols exist among clinicians; insufficient research data to recommend best clinical practice • some suggest ↑ length of retainer wear ↓ relapse • images of relapse shown to both pts and parents can ↑ compliance with retainers and ↓ relapse • GDPs should be actively informed and engaged with pts continued retention • long-term management of retention by GDP is dependent on training, communication between orthodontist/GDP and remuneration • adherence of VFR wear ↓ over time due to the negative impact of retainers on quality of life and pragmatic issues related to retainer wear • lack of follow-up appointments and immaturity of participants prompted independent decisions to taper and cease retainer wear	Destang & Kerr, 2003 Thickett & Power, 2010; Jäderberg et al., 2011 Shawesh et al., 2010 Littlewood et al., 2016; Al-Moghrabi et al., 2021 Tofeldt et al., 2007 Lin et al., 2015 Johnston & Littlewood, 2015 Molyneaux et al., 2021 Al-Moghrabi et al., 2019
Recommended reading	Parvizi et al., 2013; Johnston & Littlewood, 2015; Littlewood et al., 2016; Al-Moghrabi et al., 2021	

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Relapse and Stability

Definition of relapse	• return of teeth to their original position or a shift in arch relationship at the end of treatment • any change in tooth position or arch relationship from that position or relationship present at debond 3 proposed divisions of relapse: • physiological recovery, i.e. return to original malocclusion • unfavourable growth • 'true relapse' due to poor treatment, i.e. expanding lower intercanine width	Horowitz & Hixon, 1969
Definition of stability	• condition of maintaining equilibrium of position of teeth	
Maturation of untreated normal occlusions	Findings from 65 cases observed from age 9yrs to adulthood: • ↓ arch length • ↓ intercanine width (especially females age 13-20yrs) • stable intermolar width • minimal OJ changes • ↑ OB • ↑ lower incisor irregularity • no predictors for cases which became irregular	Sinclair & Little, 1985
Relapse in cases treated with Xtn of first premolars	65 cases, Edgewise mechanics with Xtns, retention period of 2yrs, mixed CI I and II cases, efforts made not to expand lower inter-canine width findings after 10yrs: • 70% became crowded (20% markedly crowded - classed as in need of re-treatment) • mean crowding was 5.25mm (range 1.96-10.4mm) • no predictors found Findings after 20yrs (31 cases): • crowding ↑ by 1mm on average • mean crowding ↑ to 6.02mm (range 2.38-11.48mm) • only 10% of pts had a clinically acceptable result • arch length and arch widths ↓ • no predictors found (OB, OJ, arch width or length) <i>Little's work generally had small sample sizes and no randomisation so interpret findings bearing this in mind, however similar findings demonstrated by others</i> • anterior tooth alignment, occlusal changes, dental arch dimensions, and pt satisfaction were evaluated 37yrs after treatment; changes were compared in Xtn and non-Xtn pts: - % of mandibular tooth alignment change was ↑ in the non-Xtn group - mandibular arch perimeter ↓ more than in Xtn group - non-Xtn group showed more long-term occlusal changes - pt satisfaction was similar for both groups	Little et al., 1981 Little et al., 1988 Vaden et al., 1997 Cotrin et al., 2020a,b
Relapse in cases treated with Xtn of second premolars	similar results to Xtn of first premolars	McReynolds & Little, 1991; Vaden et al., 1997
Relapse in cases treated by serial Xtn	14 cases, followed for 10yrs: • similar arch length and width changes as above • no predictors found	Little et al., 1990a
Relapse in cases treated with active expansion	26 cases in mixed dentition followed for a minimum of 6yrs: • 89% demonstrated crowding • out of all groups studied this group showed the worst relapse	Little et al., 1990b

	- no differences for long-term intermolar width stability in pts treated with palatal expansion in the mixed dentition versus the permanent dentition - absence or presence of crossbite did not affect stability	Mohan et al., 2016
Relapse in cases showing generalised spacing	30 cases observed for 10yrs, Edgewise mechanics: - all arch widths and arch length ↓ - satisfactory stability with 50% of crowded cases being only 'minimally irregular' - spacing did not reopen suggesting a continuation of the constrictive trend	Little & Riedel, 1989
Other long term studies	- cases studied for 12yrs, mixed Xtn and non-Xtn similar findings: - used different method for assessing crowding (they used mm of space available, not Little's Irregularity Index) - some evidence that long-term retention will ↓ relapse 72% of cases relapsed - degree of post-treatment irregularity of incisors is very similar whether Xtn or non-Xtn is used - no difference in incisor irregularity index for Xtn and non-Xtn 2yrs post retention - bonded retainers have no effect on stability of maxillary incisors in long term, but effectively maintain mandibular incisor alignment 8yrs post retention - no difference in relapse 37yrs after treatment in non-Xtn and Xtn (4 premolars) group	Sadowsky & Sakols, 1982 Paquette et al., 1992; Luppapornlarp & Johnston, 1994 Erdinc et al., 2006 Steinnes et al., 2017 Cotrin et al., 2020b
Treating cases to "APo"	- there is no evidence that aligning lower incisor tips to APo (proposed by Rayleigh Williams) will → stable result and avoid incisor irregularity - research shows 62% of cases relapse away from APo position towards their original position	Houston & Edler, 1990
Altering pt's archform	- there is strong evidence that unless the pt's pre-existing archform is maintained then relapse will occur - the ↑ change in archform, the ↑ risk of relapse - exceptions to this are: - mild CI III cases - CI II/2 with mild crowding - retroclined LLS (trapped in the palate) - where a digit sucking habit is present - bimaxillary proclination cases - cases with very mild crowding - meta-analysis of >1000 pts showed intercanine width ↑ 2mm during treatment and relapses the same post treatment - suggestion in literature that expansion of interpremolar width is more stable	Felton et al., 1987 De la Cruz et al., 1995 Mills, 1968 Keating, 1985, 1986 Paquette et al., 1992 Burke et al., 1998 BeGole et al., 1998
Pericision (or circumferential supra-crestal fiberotomy, CSF)	- Reitan observed directionally deviated periodontal fibres following orthodontic derotation of a tooth in Beagle dogs - Edwards tattooed lines on gingival tissues prior to derotation; this clearly showed the elastic re-rotating effect of unpericised gingival fibres - long term prospective studies confirm that CSF ↓ relapse of rotations (statistically and clinically significant differences found) - CSF and a full-time removable retainer provide a clinically significant reduction in relapse (approx 2mm) over 1yr, compared to using a removable retainer alone	Reitan, 1967 Edwards, 1970 Edwards, 1988 Taner et al., 2000

	• CSF thought to ↓ rotational relapse by around ⅓ • care needed if perio disease or thin gingival biotype especially labial to lower incisors	
Interproximal enamel stripping (IPR)	• one contention exists that lower incisors with near parallel sides maintain their alignment more readily than triangular shaped incisors • some of most stable results published include IPR of 2mm of enamel from lower incisors after alignment, at debond and during retention, this is supplemented by CSF with no retainer appliances • this contention is now disputed as it is thought that relapse cases were excluded from the published results • IPR is equally effective as positioners or bonded retainers for lower arch alignment	Peck & Peck, 1972 Boese, 1980 Gilmore & Little, 1984 Tynelius et al., 2013
Relapse of skeletal changes	• Herbst appliance treatment on 8yr old children with severe CI II malocclusions treated with HG and Herbst for 5mths, retained for 3-5yrs examined at 17yrs findings: - mandibular protrusive effect had been lost (3.9-1.5mm) - maxillary growth inhibition had continued • evidence suggests that only max influenced by about 1mm, this effect may be negated by growth rotations • continued 'active retention' using a bite plane effect may be needed in cases with residual growth and a Sk discrepancy until growth has subsided to adult levels • pubertal growth spurt for pts with deep bite occurs 1.5-2yrs later than open bite pts	Weislander, 1993 Mills, 1978 Nanda & Nanda, 1992
Factors most likely to relapse	• diastemas/spacing • rotations • OB • CLP pts • archform changes • altered lower labial segment position • periodontally involved teeth	Edwards, 1977 Edwards, 1970, 1988 Sadowsky & Sakols, 1982 De la Cruz et al., 1995 Mills, 1968
Risk factors for post treatment relapse	• pre-treatment irregularity of ant max teeth • incomplete alignment during treatment • expansion of the max arch segment • rotational displacement • interdental spacing	Surbeck et al., 1998
Minimising relapse	Pre-treatment • consider Xtn of very displaced teeth/rotated teeth During treatment • maintain existing archform (exceptions listed previously) • maintain intercanine width • do not alter the AP position of the LLS (teeth in position of equilibrium with 'extrinsic' and 'intrinsic' forces) • proclination of LLS by >7° then expect 50% relapse • placing lower 2-2 outside lower 3-3 • correct rotations early in treatment (and overcorrect if using Begg technique) - carry out CSF prior to debond • consider interproximal enamel reduction for triangular teeth to ↑ area of interproximal contact • active retention for Sk discrepancies throughout growth • obtain an adequate edge/centroid relationship - lower incisor edge 0-2mm in front of upper root centroid • move upper incisors to within lower lip control • maximise interdigitation	Little et al., 1988 Mills, 1968; Proffit, 1978 Mills, 1968 Zachrisson, 1997 Reitan, 1969 Boese, 1980 Peck & Peck, 1972 Nanda & Nanda, 1992 Houston, 1989 Pancherz & Fackel, 1990; Lloyd & Stephens, 1990

	Pre-debond • carry out CSF, CSF has role in ↓ relapse from crowding • consider interproximal enamel reduction for triangular teeth to ↑ area of interproximal contact • labial fraenectomy prior to debond produces scar tissue which minimises chances of diastema re-opening During retention • active retention for Sk discrepancies throughout growth • bonded retainers • no evidence on best practice in managing relapse of LLS	Taner et al., 2000 Boese, 1980; Peck & Peck, 1972 Pinson & Strahan, 1974 Nanda & Nanda, 1992 Yu et al., 2013
Third molars do not cause LLS crowding	Study groups included: - absent 8s - impacted 8s - aligned and functioning 8s - extracted 8s 10yrs previously Findings showed no significant differences between groups: - for LLS crowding or the amount of crowding - in growth pattern • there is no justification for the removal of 8s on the grounds of LLS crowding	Ades et al., 1990 Harradine et al., 1998; RCS, 2020
Theories for aetiology of LLS crowding	1) proclination of LLS and expansion of intercanine width during orthodontic treatment 2) anterior component of force (equivocal evidence) - a relationship occurs between LLS crowding and occlusal force but this may not be cause and effect relationship 3) late mandibular growth/significant growth rotation 4) mesial drift 5) presence of third molars (no evidence) (uncertain) 6) lack of interproximal wear 7) tooth size discrepancies (triangular incisor crowns ↑ irregularity) 8) tight interproximal contacts ↑ irregularity 9) arch length increased during mixed dentition 10) periodontal disease allowing drift	Mills, 1968; Little et al., 1981; Felton et al., 1987 Southard et al., 1989, Southard et al., 1990 Björk & Skieller, 1972 Southard et al., 1992 Ades et al., 1990 Richardson, 1989 Begg, 1954 Peck & Peck, 1972 Southard et al., 1990 Little et al., 1990b
Recommended reading	Blake & Bibby, 1998; Yu et al., 2013	

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Risks

Iatrogenic/Deleterious Effects of Orthodontic Treatment

Intra-oral Iatrogenic Damage

Extra-oral Iatrogenic Damage

Systematic Effects of Treatment

Pain and Orthodontics

Periodontal Problems Related to Appliance Wear

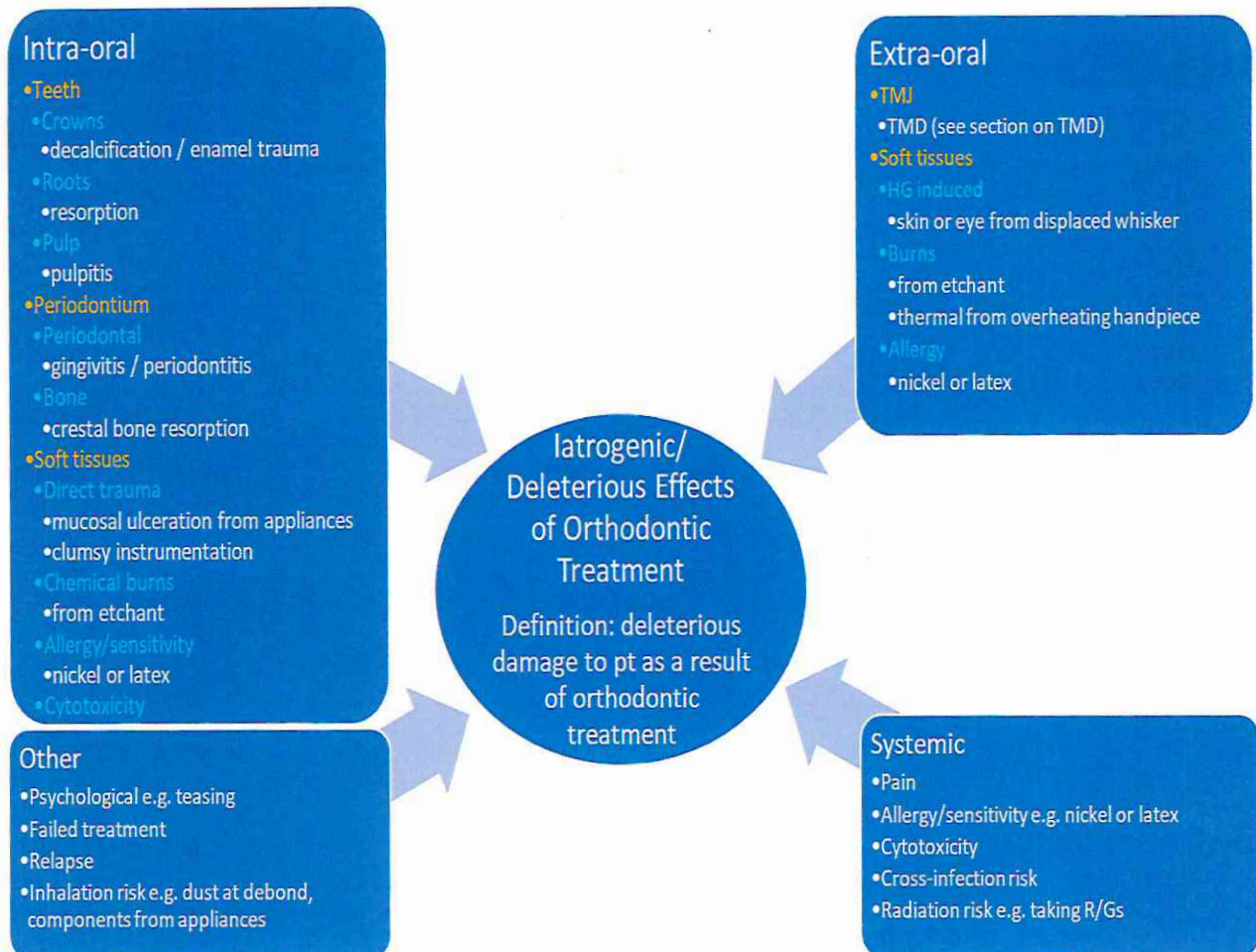
Trauma and Orthodontics

Risk Benefit

Medicolegal Aspects of Practice

Iatrogenic/Deleterious Effects of Orthodontic Treatment

Definition	Deleterious damage to the individual pt as a result of orthodontic treatment	
Intraoral effects	Teeth - crowns - decalcification - enamel trauma - acid etch - roots - resorption - pulp - pulpitis Periodontium - periodontal - gingivitis - periodontitis - burns - bone - crestal bone resorption Soft tissues - direct trauma - mucosal ulceration due to appliances - trauma from HG whisker - clumsy instrumentation - allergy/sensitivity - cytotoxicity	
Extraoral effects	TMJ - TMD (see section on Temporomandibular Dysfunction) Soft tissues - HG induced - eye damage from displaced HG whisker - skin trauma from displaced HG whisker - bruising from HG strap (uncommon) - allergy - nickel induced sensitivity associated with HG - latex - can affect pt, operator or support staff - burns - chemical from etchant/self-etch primer (SEP) - thermal from overheating handpiece - infections - angular cheilitis	
Systemic effects	- pain - allergy/sensitivity to nickel and latex - cytotoxicity - bacterial endocarditis - cross-infection - operator to pt - pt to operator - pt to pt - any source to 3rd party - radiation protection and risks	
Other effects	- psychological - teasing - failed treatment - risk to airway and eyes - relapse - argument that treatment flattens (dishing) profile (see section on Extractions and Facial Profile) - inhalation of dusts produced during debond	Johnston et al., 2009
Recommended reading	Ellis & Benson, 2002	



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Intra-oral Iatrogenic Damage

CROWN DAMAGE		Recommended reading: Bishara & Ostby, 2008; Chambers et al., 2013; Benson et al., 2019
1. Decalcification		
Aetiology	- due to attack by acidic by-products of plaque metabolism - requires 4 elements: 1) plaque - <i>S. mutans</i> count ↑ in FA wearers 2) substrate - depends on diet 3) susceptible tooth surface - depends on pt variability 4) time - in contact with tooth surface - acidic drinks ↑ the risk, e.g. carbonated/citrus drinks - salivary factors - pH, flow, buffer capacity 5x ↑ in levels of <i>S. mutans</i> immediately after FA - little difference in bacteria comparing ceramic versus metallic brackets - shift in microbial composition during FA persisted up to 1yr post debond	Kidd & Smith, 1991 Ludström & Krasse, 1987a Anhoury et al., 2002 Ireland et al., 2014
Incidence	↑ prevalence of 'white spot lesions' (WSL) in orthodontic pts - large incidence range 8-97%, due to different methods of assessment 33-50% of pts are found to have at least one white spot after treatment: 23% of bonded or 17% banded max incisors 2-6.6% had cavitation 9-24% of non-orthodontic pts have at least WSL - positive correlation between oral hygiene and caries incidence in FA wearers - can occur within first mth of FA wear and can occur between treatment visits - often related to the length of treatment - surprisingly no relationship between length of treatment and number of lesions - no difference between male and female - progression to cavitation is low (2%) 5yrs post treatment, pts have ↑ incidence of WSL compared to that of non-orthodontic pts - FA pts have ↑ number of WSL than clear aligner pts; WSL in FA pts are smaller and deeper than WSL in clear aligner pts	Willmot & Brook, 1999 Ast et al., 1956; Mitchell, 1992; Boersma et al., 2005 Geiger et al., 1982; Sandvik et al., 2006; Gorelick et al., 1982; Banks et al., 1987 Mizrahi, 1982 Zachrisson & Zachrisson, 1971a Zachrisson & Zachrisson, 1971b Øgaard et al., 1988 Gorelick et al., 1982 Øgaard et al., 2006 Banks et al., 2000 Øgaard et al., 1989 Albhaisi et al., 2020
Site	- fixed - labially (labial appliance)/lingual (lingual appliance) - URA - palatally - order of prevalence -maxillary lateral (23%); mandibular canine (18%); mandibular 1st premolar (17.5%); mandibular 1st molar; mandibular 2nd premolar; maxillary canine -gingival 1/3 > middle 1/3 > incisal 1/3 - influenced by dominant hand brushing, i.e. in right-handed pt decalcification occurs on right side through less effective cleaning - yes - no	Gorelick et al., 1982; Geiger et al., 1992 Årtun & Brobakken, 1986 Mizrahi, 1983 Zachrisson, 1976 Addy et al., 1990 Willmot, 2004
Prevention	- appropriate pt selection, i.e. exclude pts with poor OH - monitor pts Education programme - dietary advice	

	- OH advice - topical fluoride, only 13% pt comply - resin sealants over labial surface Toothbrushing - manual brushing with V-shaped brush head 78% more effective - powered more effective than manual - use of ultrasonic brushes not contraindicated Fluoride • toothpaste - 5000ppm reduces WSL by 32% - 1000-1250ppm reduces WSL by 23% - 2400-2800ppm reduces WSL by 36% - <500ppm no benefit • mouthwash - daily use 0.05% (226ppm) NaF enhances prophylaxis - once weekly 0.2% (900ppm) NaF effective • acidulated-phosphate-fluoride - 250ppm NaF at pH5.5 effective as 1000ppm at pH 7 • stannous fluoride (Tin (II) fluoride) - binds gram +ve bacteria preventing attachment to enamel - prevents sucrose entering the cell, preventing fermentation • fluoride varnish or spray - ↓ WSL when used - fluoride bead, fluoride slow releasing device attached to molars; good for non-compliant pts - regular ammonium fluoride varnish ↓ prevalence of advanced WSL • foam - 12,300 ppm, applied every 2mths during FA treatment may ↓ incidence of new WSL • pharmaceutical prevention - chlorhexidine ↓ WSL - yes (causes bacterial cell death and inhibits adherence of microorganisms to tooth surface) - no - stains composite and glass ionomer - not recommended for regular use • bonding materials and techniques - indirect bonding technique may ↓ WSL formation - resin modified glass ionomer - ineffective - effective • ligation - self-ligation ↓ plaque - wire ligation ↓ plaque compared with elastomeric ligation - fluoride releasing elastics - very high initial fluoride release; effective in reducing WSL: - yes - no - poor physical properties	Geiger et al., 1992 Banks & Richmond, 1994 Schätzle et al., 2009 Yaacob et al., 2014 Garcia-Gody & de Jager, 2007 Sonesson et al., 2014; Benson et al., 2019 Benson et al., 2005 Zero et al., 1992 Koch et al., 1982 Hove et al., 2006 Benson et al., 2019 Al Ibrahim et al., 2010 Sonesson et al., 2020 Benson et al., 2019 Anderson et al., 1997; Puig Silla et al., 2008 Bratthall et al., 1995; Lundström & Krasse, 1987b Atila et al., 2020 Chung et al., 1998 Gorton & Featherstone, 2003 Türkkaharaman et al., 2005 Tinsley et al., 2003 Mattick et al., 2001 Benson et al., 2005 Banks et al., 2000
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	- other methods: -regular use of probiotics during FA ↓ <i>S. mutans</i> and <i>Lactobacillus</i> levels in saliva -enamel irradiation with CO₂ laser has inhibitory effect on WSL formation during treatment -identify, prevent or remove stagnation areas, ↓ flash around brackets -fluoride release from composite resin -MDPB - antibacterial agent incorporated into resin ?effective -compomer has the same failure rate as composite but fluoride may give added benefit of ↓ decalcification -removal of archwires for a visit -remove appliance (last resort)	Alp & Baka, 2018 Raghis et al., 2018 Årtun & Brobakken, 1986 Ghani et al., 1994 Ireland et al., 1996 Millet et al., 2000
Treatment	- non-cavitated lesions can remineralise - spontaneously ↓ in size and appearance - significant ↓ in size in first 6-12 weeks following FA removal - remineralisation continues for further 6mths - use of high fluoride contraindicated -causes hypermineralisation if surface layer preventing further diffusion of ions -fixes size and appearance of lesion - monthly use of fluoride varnish improves WSLs - acid etch surface aids diffusion and repair Chewing gum - use of sugar free chewing gum recommended - use 5x per day for 3 weeks reduced WSL Casein Phosphopeptide-Amorphous Calcium Phosphate - caesin from dairy products maintains calcium and phosphate ions on tooth surface - promotes diffusion of ions into body of lesion - may buffer plaque acid ↓ pH and duration - source of nitrogen for ammonia aiding pH reduction - no benefit in caries prevention compared to fluoride toothpaste however some benefit in WSL regression - effective in prevention and treatment of WSL - may ↓ <i>S. mutans</i> binding Microabrasion 2 techniques: -37% phosphoric acid and pumice (less aggressive) -18% hydrochloric acid and pumice (more aggressive) - alters enamel optical properties improving appearance Resin infiltration - uses 15% hydrochloric acid to remove surface then unfilled resin added - reported ↑ efficiency in treatment of chalky white spots Vital tooth bleaching - non-destructive means of improving WSL appearance Restoration	Hyde et al., 2016 Willmot, 2004 Willmot, 2004; van der Veen et al., 2007 O'Reilly & Featherstone, 1987 Øgaard et al., 1988 Höchli et al., 2017 Hicks et al., 1984 Manning et al., 1992 Reynolds et al., 1982 Cochrane et al., 2008 Reynolds, 1998 Reynolds et al., 1982 Raphael & Blinkhorn, 2015 Pithon et al., 2019 Guggenheim et al., 1999 Murphy et al., 2007; Welbury & Carter, 1993 Hyde et al., 2016
2. Enamel trauma		
Aetiology	- metal brackets -lower 3 brackets can damage 3 cusps during canine retraction - ceramic brackets -lower brackets can abrade 21/12 -debond more commonly occurs between composite/enamel as composite/ceramic bond ↑ hence there is ↑ risk of enamel damage	McGuinness, 1992 Swartz, 1988 Jeiroudi, 1991

	• damage to enamel with burs when debonding or removing excess composite • careless use of band seater • ↑ interproximal stripping → dentine hypersensitivity	Cambell, 1995 McGuinness, 1992 Meeran, 2013
Prevention	• careful bracket positioning - removal of certain brackets during canine retraction if necessary - do not place ceramic brackets on lower incisors in cases with ↑/normal OB • careful operating, particularly when working on 'risk' teeth, e.g. heavily restored teeth, hypoplastic teeth • use tungsten carbide burs in slow handpiece to remove composite • care when debonding ceramic brackets: - remove composite around bases before debonding - ceramic brackets with plastic inserts - CO₂ lasers for debonding • electrothermal debonders can be used • correct technique and professional application of fluoride for interproximal stripping	Cambell, 1995 Stewart et al., 2015 Ma et al., 1997 Sheridan et al., 1986a,b Meeran, 2013
Treatment	• AVOIDANCE if possible • composite restorations on worn cusps/fractured teeth	
ROOT DAMAGE		
Resorption	Recommended reading: Brezniak & Wasserstein, 2002a,b; Barker et al., 2010; Parvizi et al., 2011; Roscoe et al., 2015; Yassir et al., 2021	
History	• first discussed by Bates, 1856, has been of major concern to orthodontists since 1927	Brezniak & Wasserstein, 1993a,b
Incidence	• around 90% pts will experience resorption but in most cases this is insignificant • some degree is inevitable during treatment with FA but is unpredictable and variable, can be severe • particularly affects: $\frac{21}{6} \frac{1}{2} \frac{1}{2} \frac{2}{6}$ • mean loss: 1.5mm Max 2mm, Mand 1mm • usually apical rather than lateral (unless using RME) • rarely compromises longevity of the teeth • severe (↑ 5mm) - 5% adults - 2% adolescents • universal resorption found in pts who had complete roots • pts with incomplete root formation did not develop normal length roots, but these were still longer than the older pt	Weltman et al., 2010 Killiary, 1999 Kennedy et al., 1983 Linge & Linge, 1983 Kennedy et al., 1983 Mirabella & Årtun, 1995; Linge & Linge, 1983 Hendrix et al., 1994 Hendrix et al., 1994
Types	• physiological - resorption of primary teeth • inflammatory • replacement - ankylosis • idiopathic - no identifiable cause OR • apical • lateral - difficult to detect lateral resorption on R/G's, CBCT improves diagnosis	Brezniak & Wasserstein, 1993a Andreasen et al., 1987; Dudic et al., 2009
Aetiology	• complex & multifactorial: pt related and treatment related	Weltman et al., 2010
Mechanism	• unknown • when orthodontic forces are applied, roots as well as bone resorb BUT cementum is repaired during periods of quiescence, if repair doesn't occur then permanent loss of root structure occurs	Brezniak & Wasserstein, 1993a,b

	Opinion divided on causes of resorption, theories include: • mechanical trauma to apex → cell death → repair → if excess then can lead to root resorption • PDL has protective effect because of fibroblast presence, if areas of the PDL have become hyalinised and need removing before tooth movement can progress, this is more likely with heavy orthodontic forces, the protective effect of fibroblast would be lost • possibly excess cementoclast and osteoclast activity • bone resorbed in preference to cementum, ? due to: - differences in collagen insertion, dense insertion in cementum so cement surface not accessible by osteoclasts - cementoid layer highly mineralised, less cellular activity - might have anti-invasion factors against blood vessels from developing (anti-angiogenic factors) • protection may come from innermost cellular layer of PDL (due to fibroblasts) with resorption occurring if osteoclasts access mineralised root tissue via breach in covering cellular layer • Wnt-responsive stem/progenitor cells contribute to physiological cementum repair • OPG gene polymorphism associated with external apical root resorption • repair greatest immediately after tooth movement • irreversible once it extends into dentine • can happen quickly; 10-35 days after application of force and usually before resorption lacunae is apparent	Brezniak & Wasserstein, 2002a,b Turkkahraman et al., 2020 De Castilhos et al., 2019 Owman-Moll et al., 1995a
Classification	• grade 1 - irregular root outline • grade 2 - <2 mm root resorption (minor) • grade 3 - >2 mm root resorption (severe) • grade 4 - resorption >1/3 of root length (extreme) • occasionally Grade 0 is added representing no resorption • Category 1: slight blunting (mild) • Category 2: up to 1/4 root length (moderate) • Category 3: over 1/4 root length (severe)	Levander & Malmgren, 1988 Kayley & Philips, 1991
Pt related risk factors	Age • equivocal • some suggest treatment before completion of root development, possibly the protective effect of pre-dentine Gender • equivocal - some found ↑ in males, some in females Ethnicity • Hispanic>White>Asian Medical history • not strong association, possible association with asthma • hypothyroidism/hypoparathyroidism - thyroxine may have protective effect Family history • siblings - heritability of 70% of resorption for 1's & lower molars Malocclusion • ↑ risk in Class III, possibly due to compensated incisors against cortical plate • malocclusions with "jiggling" forces • no risk factors related to ↑ OJ and OB	Brezniak & Wasserstein, 2002b Linge & Linge, 1983 Kjaer 1995; Baumrind et al., 1996 Sameshima & Sinclair, 2001a McNab et al., 1999 Shirazi et al., 1999 Harris et al., 1997 Kaley & Phillips, 1991

	- treatment of ectopic canines, may get ↑ resorption of 2 and 4, this may be due to the length of treatment - diminutive 2 are not more susceptible Habits - bruxism, nail-biting (evidence is weak) Tooth type & series $\underline{2} > \underline{1} > \text{lower incisor} > \text{distal root of lower molar}$ Root form - it has been suggested blunt or pipette-shaped roots or single rooted teeth more prone to root resorption - however meta-analysis has found no association between unusual root morphology and root resorption Dental anomalies - no association shown Trauma - roots showing resorption due to previous trauma have ↑ risk of further resorption, although no ↑ risk if these teeth show no pre-treatment resorption - root treated teeth have ↓ resorption provided RCT is sound	Woloshyn et al., 1994 Kook et al., 2003 Odenrick & Brattström, 1985 Weltman et al., 2010 Levander & Malmgren, 1988 Weltman et al., 2010 Lee et al., 1999 Malmgren et al., 1982 Remington et al., 1989; Drysdale et al., 1996
Treatment related risk factors	- predominantly moderate to low quality evidence re: orthodontic mechanotherapies and influence on external root resorption Duration of treatment 2-phase versus 1-phase (CI II) - less in 2-phase unless ↑ OJ reduction in phase 2 - long treatment - ↑ resorption Magnitude of force - heavy > light forces - heavy forces 12x ↑ in resorption crater versus control Type of tooth movement - intrusion 4x > extrusion - intrusion force - 225g (4x) > 25g (2x) > control - rotation - ↑ in medial 1/3 - torque - especially against cortical plate - continuous versus discontinuous - no difference - intrusive forces and continuous forces cause external root resorption Extraction patterns (inconclusive) - Xtn of 4 premolars > non-Xtn; Xtn 4s = non-Xtn Archwires - superelastic NiTi > SS - archwire sequence - no difference Orthodontic appliances - self-ligating = conventional ligation - clear aligner therapy = FA (except for UR2 where FA caused more resorption) Mechanics - CI II traction/rectangular archwires	Currell et al., 2019; Yassir et al., 2021 Brin et al., 2003 Roscoe et al., 2015; Currell et al., 2019 Brudvik & Rygh, 1994; Chan & Darendeliev, 2006; Roscoe et al., 2015 Han et al., 2005 Harris et al., 2006 Jimenez-Pellegrin & Arana-Chavez, 2004 Kaley & Phillips, 1991; Horiuchi et al., 1998 Owman-Moll et al., 1995b Currell et al., 2019 Sameshima & Sinclair, 2001b Weiland et al., 2003 Mandall et al., 2006 Linge & Linge, 1983 Scott et al., 2008; Pandis et al., 2008 Gandhi et al., 2021 Levander & Malmgren, 1988
Prevention	- dental history and examination: - pre-treatment warnings during consent - check if family history of resorption	

	- review pre-treatment root lengths: consider DPT pre-treatment R/G's, periapical/occlusal if necessary - stop adverse habits - be wary of traumatised teeth • light forces • minimise treatment length • monitor progress: - R/G $\frac{1}{12}$ into treatment, however opinion is divided due to A.L.A.R.P. - 2D R/Gs may overestimate external apical root resorption versus CBCT • start orthodontic treatment whilst young, ? pre-dentine gives a protective effect • reconsider treatment aims when resorption is apparent, consider 2-3mth break if resorption identified • sound orthodontic judgement/monitoring can ↓ risks • use of thyroxine; studies indicate roots of pt administered with drug had ↓ resorption than those who had not; thyroxine might have indirect effect on resorption by ↑ alveolar bone resorption	Atack, 1999 Levander & Malmgren, 1988 Gandhi et al., 2021 Linge & Linge, 1983 Levander et al., 1994; Roscoe et al., 2015 Poumpros et al., 1994; Loberg & Engström, 1994; Shirazi et al., 1999
Long-term effects	• loss of tooth - very low incidence found due to severe resorption • apical root loss of 3mm is equivalent to 1mm of crestal bone loss	Remington et al., 1989; Levander & Malmgren, 2000 Kalkwarf et al., 1986
PULP DAMAGE		
Incidence	• pulpitis - 90% get pain in the first mth • rarely leads to loss of vitality • transient pulpitis common with low speed handpieces	Anstentig & Kronman, 1972 Zachrisson, 1976
Aetiology	• FA • ↑ in pulpitis in previously traumatised teeth • composite polishing burs/stones • electrothermal debonders - significant hyperaemia	Brin et al., 1991 Zachrisson, 1976 Takla & Shivapuja, 1995
Prevention	• care when treating previously traumatised/RCT teeth • monitor baseline vitality and repeat 3mthly • use light forces • care needed not to overheat teeth when removing composite at debond • care when using electrothermal debonders, do not heat > 5°C for longer than 5-10 seconds, cool tooth with water immediately to counteract microwave effect	Atack, 1999; Sandler et al., 2021 Mangnall et al., 2013
SUPPORTING TISSUES		
1. Periodontal inflammation	See section on Periodontal Problems Related to Appliances Wear	
2. Cytotoxicity		
Aetiology	• bonding agents - one to one agents cytotoxic for 30/7 - paste systems toxic for 2yrs • elastics - affects fibroblasts in vitro, no effects in vivo • archwires - no effect • bands and brackets - no effects • Ni-free brackets best biocompatibility • TADSs - containing SS ↓ mouse osteoblast viability, TADs containing Ti alloys no effect on same cells • clear aligners, e.g. Invisalign, no cytotoxicity or estrogenicity	Tell et al., 1988 Holmes et al., 1993 Grimsdottir et al., 1992 Retamoso et al., 2012 Malkoc et al., 2012 Eliades et al., 2009
Prevention	• all mutagenic bonding agents now withdrawn	Fredricks, 1981

3. Alveolar bone loss		
Incidence	• uncommon • crestal bone loss is minimal: 0.5-1mm • bone loss during treatment unrelated to previous loss • long-term effect is minimal	Kennedy et al., 1983; Zachrisson, 1976 Sharpe et al., 1987
SOFT TISSUE DAMAGE		
1. Mucosal trauma		
Incidence	• common	McGuinness, 1992
Aetiology	• ulceration from archwires - long distal ends, long spans of archwires, e.g. across Xtn spaces • displacement of HG whisker • initial ulceration from brackets • acid burn from etch/self-etch primer • thermal burn - hot instrument, electrothermal debonder • clumsy instrumentation	
Prevention	• careful operating • trim or turn in long ends • turn in hooks • bumper sleeving on long spans of archwires, lacebacks • safety straps on HG to keep whisker within HG tube • use of wax as necessary	
Treatment	• advice to pt regarding care of appliance • topical applications for ulceration as necessary	
2. Allergy		
Incidence	• rare • 5-12x concentration of nickel required to provoke mucosal lesions compared with skin lesions • ↑ nickel release in saliva immediately after FA placement, no significant difference between controls and FA pts after 3 weeks • female > male	Bass et al., 1993 Dunlap et al., 1989 Gjerdet et al., 1991
Aetiology	• FA - nickel is the most common allergen • elastics • bonding agents • latex	Hutchinson, 1994 Nattrass et al., 1999
Treatment	• patch testing can be undertaken • remove the sensitising agent • diagnosed nickel hypersensitivity: - archwires - replace NiTi with SS (low Ni content), TMA (nickel-free), fibre reinforced composite wires, pure titanium or gold-plated wires - brackets - alternative nickel-free brackets include ceramic, polycarbonate, titanium, gold • can use clear aligners as opposed to FA	Patel et al., 2009

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Extra-oral Iatrogenic Damage

TMJ	See section on Temporo-Mandibular Dysfunction (TMD)	
SOFT TISSUE DAMAGE		
1. HG induced		
Area affected	Eyes - face-bow injury, sympathetic ophthalmitis Skin - injuries associated with displacement of HG whisker - bruising associated from neck strap - nickel allergy contact dermatitis Hair - HG-induced temporary pressure alopecia	Holland et al., 1985; Booth-Mason & Birnie, 1988 Samuel & Jones, 1994 Liu et al., 2019
Incidence	- uncommon: 31 out of 859 orthodontic practitioners reported injuries → 33 pts suffered injuries using Kloehe facebows, 17 of these injuries occurred at night - eye injury uncommon but serious when occurs	Samuels et al., 1996
Prevention	- usage of 2 safety mechanisms - safety spectacles during fitting and adjustments - careful adjustments of HG to maintain good fit - not too tight/loose - safety products, e.g. NiTom locking facebow, straps, blunt-ended whiskers, snap release HG - clear instructions given to pt/parents regarding wear and care of HG (written and verbal) - advise not to play in HG - any problems to discontinue wear and contact orthodontist - advice to seek ophthalmic opinion if trauma occurs involving the eye, however small the trauma	BOS, 2013 Postlethwaite, 1989; Samuels & Jones, 1994; Samuels et al., 1996
2. Allergies		
Incidence	- nickel - more common extraorally - usually HG strap or whisker 1% pts experience contact dermatitis to zips etc, and of these, 3% claimed to have rashes with orthodontic appliances - bonding agents - rare - latex	BOS, 2012 Burden & Eedy, 1991 Staekjaer & Menne, 1990 Hutchinson, 1994 Nattrass et al., 1999; BOS, 2014
Aetiology	- metal studs/attachments on HG - bonding agents - some withdrawn from market, e.g. Monokok primer - gloves, elastomerics	Burden & Eedy, 1991
Prevention	- tape can be placed around exposed metal of HG to ↓ allergic reactions - remove appliance if necessary - hypoallergenic gloves	
3. Infections		
Angular cheilitis	- uncommon - incidence 5-11%	Cross & Short, 2008 Cross et al., 2010
Aetiology	- immuno-compromised ? nickel allergy	Yesudian & Memon, 2003
Treatment	- debridement - use of miconazole nitrate 2% gel - blood tests if lesion fails to resolve	Cross & Short, 2008

4. Burns		
Incidence	• uncommon	McGuinness, 1992
Aetiology	• chemical - etchant/self-etch primer • physical - thermal from overheating handpieces - thermal from electrothermal debonding	
Prevention	• care when operating • safety spectacles	

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Systemic Effects of Treatment

ALLERGIES	See sections on Relevant Medical Disorders and Intra-oral Iatrogenic Damage	Patel et al., 2009; Alawsi et al., 2020
1. Nickel		BOS, 2012
Incidence	9-28% of population - not usually a problem intraorally during treatment as ↑ concentration of nickel needed to provoke mucosal lesions compared to skin lesions - more common in females 30%, 3% males	Dunlap et al., 1989 Dunlap et al., 1989 Kerosvo et al., 1996
Aetiology	- archwires - bands and brackets - in artificial saliva at 37°C, 37x more nickel is released than chromium in first 2 weeks BUT clinically pts do not show a significant or consistent ↑ in nickel blood levels in the first 4-5mths of treatment - both nickel and chromium are released in levels below the average dietary intake - EOT - whisker, neck strap, head cap - previous sensitization through jewellery may be involved - orthodontic treatment preceding piercing ↓ risk of nickel allergy by factor 1.5-2	Barrett et al., 1993; Bishara et al., 1993 Bass et al., 1993 Fors et al., 2012
Treatment	- removal of appliance/archwire - patch testing to establish cause - caution with pts with history of atopic dermatitis to nickel - use nickel-free appliance alternative if known allergy	Leite & Bell, 2004 BOS, 2012
2. Natural Rubber Latex (NRL)		BOS, 2014
Incidence	1% general public 5-15% health care workers 24-60% pts with spina bifa	Hanson & Lobner, 2004
Types of reaction	- irritant contact dermatitis - allergic contact dermatitis (type IV sensitivity) - common, dermatological problems - immediate Type 1 response - risk of anaphylaxis in pre-sensitised pts	Field & Fay, 1995 Field et al., 1998
Treatment	- test for NRL allergy to establish sensitivity - use NRL-free products - early morning appointments, use filters - ↓ NRL in environment	BOS, 2014
BACTERIAL ENDOCARDITIS	See section on Relevant Medical Disorders - guidelines advise that antibiotic cover (ABC) should not be given to children/adults with structural cardiac defects undergoing dental intervention procedures and that chlorhexidine mouthwash should not be given - NICE wording updated in 2015 to state ABC "not recommended routinely"	NICE Guideline, 2016
Rationale for guidelines	- no consistent association between having dental procedures and Infective Endocarditis (IE) - regular toothbrushing presents ↑ risk of IE than a single dental procedure - clinical effectiveness of ABC not proven (risks of fatal anaphylaxis, not cost effective) - incidence of IE in England ↑ significantly after introduction of NICE 2008, prompting review of guidelines	Dayer et al., 2015 NICE Guideline, 2016
Advice to pts	Give pts clear and consistent information including: - benefits and risks of ABC - why ABC no longer routinely used - the importance of maintaining good oral health	

	- information about symptoms of IE and when to seek help - check with cardiologist/GP	
CROSS INFECTION		
Types	- pt to pt - pt to operator - operator to pt - any source to 3rd party	
Agents involved	- bacterial - viral - fungal - prion and new variant CJD (Creutzfeldt-Jakob disease)	Porter & Scully, 2000
Prevention	- medical history - identify 'at risk' pts, screening, testing procedures - proper sterilisation/disinfection procedures - sterilisation of tungsten carbide debonding burs was shown to be effective against S. mutans regardless of pre-sterilisation method - ultrasonic cleaning of tried-in bands ↓ but does not completely eliminate salivary proteins, there is a need to investigate a more effective method of cleaning - use cross-infection control measures, e.g. safety spectacles, gloves, face-masks - vaccination, e.g. hepatitis B - consider whether bracket recycling appropriate	Lee et al., 2020 HTM 01-05, 2009; Haworth et al., 2021 Sheriteh et al., 2010 Benson & Douglas, 2007 Haworth et al. 2021 Oliver et al., 1997; BOS, 2011
Pandemics, e.g. COVID-19	- airborne disease can pose a threat to pts and operators - new ways of operating may have to be developed to ↓ risks, e.g. -↑ use of digital technologies -↓ use of open plan surgeries -virtual consultations	Lee et al., 2020 Lee et al., 2020 Byrne & Watkinson, 2021
OTHER		
Radiation	↑ radiation exposure, always follow A.L.A.R.P. principle (see section on Radiation Safety)	Isaacson et al., 2015

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Pain and Orthodontics

Definition of pain	Unpleasant sensory and emotional experience associated with actual or potential tissue damage	Harris et al., 2018
Features	• common experience for pts undergoing any form of dental treatment • can be experienced at all stages of treatment • 95% orthodontic pts reported experiencing pain • pts experience some degree of discomfort after placement of orthodontic appliances, this is expressed as feelings of pressure, tension, soreness of teeth and pain • principal barrier to seeking orthodontic treatment • orthodontic appliance-induced pain may negatively affect pt cooperation • orthodontists underestimate level of pain caused during orthodontic treatment	Brown & Moerenhout, 1991 Kvam et al., 1987 Patel, 1992; Krishnan, 2007 Oliver & Knapman, 1985 Krukemeyer et al., 2009
Pain perception	• sensory reaction to pain is complex • mainly modulated by higher centres of the central nervous system (CNS) • subjective - wide range of individual responses when similar forces were applied to the teeth • multifactorial Influenced by: • psychological factors: influence adaptation to pain and discomfort • pain experienced by pts does not seem to be related to magnitude of the force but related to psychological wellbeing • social class • rise of impulses from the brain stem • <i>gate control theory</i>: nociceptive impulses can be altered at dorsal horn of spinal cord causing less or no pain sensation: - nociceptive impulses entering a calm and normal functioning brainstem: the impulse may never reach the higher centres to elicit a pain response - in contrast, if same impulse enters brainstem of pt suffering from chronic pain, they may produce a significant pain response → pt who had painful dental treatment would experience more pain as ↑ sensitization • previous pain experiences - brain cortex stores all memory of past experiences so previous pain experiences may influence clinical pain - repetition of similar circumstances can generate clinical pain associated with former traumatic experiences, even though no noxious stimulation occurs • emotional state - when the nociceptive impulses enter thalamus, they are directed to the cortex and limbic structures where pain is evaluated at an emotional level - perception of pain by the limbic system can precipitate certain emotions, e.g. fear/rage - stress also significantly influence the degree of pain; the ↑ in sympathetic nervous activity (SNS) occurs even though no physical threat is present - there is correlation between stress and frequency/severity of pain	Burstone, 1964 Jerjes et al., 2007 Brown & Moerenhout, 1991 Feinmann et al., 1987 Melzack & Wall, 1965

	- stress and anxiety cannot be differentiated from each other: anxiety ↓ pain threshold levels, → perception of normally painless impulse to be perceived as painful • behavioural traits - Rotter factors, e.g. perceived severity of malocclusion and personal control orientation, affects pt behaviour during orthodontic treatment • gender - females more likely than males to report severe pain and for longer duration (classically) - evidence equivocal - separator placement - females experience more pain - initial archwire placement - no gender differences • age - difficult to measure age-related differences in pain as there are different treatment protocols for adolescents and adults - some studies found that younger pts feel ↑ pain than older pts - others found no difference • expectation and placebo effect - psychological management of pain by informing the pt about the procedure is important - trusting relationships between orthodontist and pt can ↓ anxiety and pain	Litt, 1996; Ireland et al., 2017 Rotter, 1966 Feinmann et al., 1987 Riley et al., 1998 Erdinç & Dinger, 2004 Pringle et al., 2009 Scheuer et al., 1996 Jones & Richmond, 1985 Ngan et al., 1989 Brown & Moerenhout, 1991 Pringle et al., 2009 Polat, 2007
Pain pathway	2 pathways - indirect and direct stimulation • indirect stimulation - inflammatory mediators, e.g. histamine, bradykinin, substance P, prostaglandins and serotonin • direct stimulation: Stimulation of afferent A-delta & C nerve fibres causing depolarisation ↓ Sensation of pain is transmitted from the pulp and/or periodontium to the CNS via nociceptive afferent fibres ↓ Impulses from trigeminal afferent neurons from 1st order neuron to spinal cord through dorsal root cells ↓ Pain stimulus is transmitted along the neuron axon by propagation of an action potential and activation of sodium channels in response to depolarisation ↓ 2nd order neurons ascend in the anterolateral tract ↓ 3rd order neurons (thalamic nuclei) PAIN PERCEIVED • neospinothalamic: fast physiologic pain • paleospinothalamic: slow pathologic pain • A-delta fibres: associated with acute pain • C fibres: associated with slower, persistent pain	Grewal et al., 2020
Mechanism of orthodontic pain	• application of orthodontic forces perceived as nociceptive input which results in activation of specific pain and inflammatory response • periodontal pain (process of pressure, ischaemia, inflammation and oedema): - immediate pain response - initial compression of the periodontal ligament (PDL) after AW placement - delayed pain response, few hours later (hyperalgesia of the PDL)	Furstman & Bernik, 1972

	• when mechanical forces are applied to the teeth, results in change in blood flow, which initiates acute inflammatory reaction in periodontal tissues • prostaglandins (histamine, bradykinin, serotonin, leukotrienes, acetylcholine and substance P) ↑ sensitivity to noxious agents → hyperalgesia • orthodontic forces also ↑ level of prostaglandins and leukotrienes (which are potent inflammatory mediators) causing ↑ blood flow and inducing chemotaxis • mechanical force application also affects neurons ("neurogenic inflammation"), this involves antidromic release of neuropeptides following stimulation of afferent nerve endings after initiation of the inflammatory reaction → role of neurofilament protein, calcitonin gene-related peptide, vasoactive intestinal polypeptide and neuropeptide Y have been identified	
Pain in orthodontics	Timing of orthodontic pain • generally starts 2hrs after appliance placement • pain peaks at 24hrs • subsides over next 5-7 days Location of pain • ↑ in ant teeth (particularly lower incisors) Pain with different brackets • conventional versus self-ligation brackets - evidence inconclusive • labial versus lingual brackets - ↑ oral discomfort with lingual brackets, related to soft tissue discomfort (tongue) • 0.022" versus 0.028" slot - perception of pain not significant Pain with different AW • no evidence that the use of any archwire for initial alignment has any effect on perceived pain Effect of different treatment • separator placement - spring versus elastomeric - spring considered less painful but not significant; pain worse at day 2 for both • removable/functional versus fixed - FA and functionals ↑ pain compared to removables - FA ↑ pain compared to removables - application of constant force in FA compared with intermittent force with removables - RCT pain low to moderate for both groups: ↑ difficulty with eating for fixed group • orthopaedic forces - craniofacial orthopaedics use mechanical forces of ↑ magnitude, when applied are transmitted and absorbed to the craniofacial complex - RME - pain during the initial phase, which ↓ as treatment progresses - HG discomfort after 24 hours, sharp decline in pain after 3 days • debonding - pain during debond is not uniform, influenced by tooth mobility and direction of force applied; intrusive forces easier to tolerate - lower incisors most painful - recommended using finger pressure/cotton roll to minimize pain - occlusal rim wax suggested for pain free debonding	Storey & Smith, 1952 Scheurer et al., 1996 Grewal et al., 2020 Papageorgiou et al., 2016 El-Angbawi et al., 2019 Wang et al., 2018 Bondemark et al., 2004 Sergl et al., 1998 Stewart et al., 1997 Weidel & Bondemark, 2015 Krishnan, 2007 Needleman et al., 2000 Cureton, 1994 Williams & Bishara, 1992 Magnall et al., 2013 Williams & Bishara, 1992 Rinchuse, 1994

Management	Pharmacological (Analgesics) • moderate quality evidence that analgesia effectively ↓ pain when compared to no treatment/placebo at 2, 6 and 24hrs • type of analgesia - paracetamol versus ibuprofen - no difference - RCT demonstrated ibuprofen shown to be more effective than paracetamol - NSAIDs inhibit COX which is responsible for formation of prostaglandins therefore, caution may need to be taken in pts with asthma - check medical history - concern that NSAIDs might slow orthodontic tooth movement by affecting osteoclast activity however, no evidence to suggest a clinically significant effect of NSAIDs on tooth movement; probably due to transient use of NSAIDs • timing of analgesia - low quality evidence suggests pre-emptive ibuprofen provides better pain relief at 2hrs than ibuprofen taken post treatment - afferent nerve impulses are blocked before they reach the CNS (treatment is preventive, not symptomatic) - if NSAIDs given preoperatively the body absorbs it before tissue damage, and subsequent prostaglandin production will ↓ inflammatory damage Non pharmacological • Cochrane Review - insufficient evidence, although laser irradiation may help to control short term orthodontic pain • RCT showed cognitive behaviour therapy significantly ↓ pain perception; pain levels comparable to pts who received ibuprofen post treatment • adjunctive modalities - TENS (transcutaneous electrical nerve stimulation) ▪ pain control during seps placement (effective within 6 secs of electrode placement) ▪ debonding of brackets - vibratory stimulation of PDL equivocal - postulated that chewing on something hard bite wafers/chewing gum immediately after adjustment helps loosen PDL fibres, reducing oedema and inflammation and restoring the lymphatic circulation - orthodontists usually advise against chewing gum, however, RCT found no evidence that sugar free chewing gum ↑ breakages but ↓ amount of ibuprofen needed by pts following initial bond up and first archwire change	Monk et al., 2017 Monk et al., 2017 Bradley et al., 2007 Salmassian et al., 2009 Arias & Marquez-Orozco, 2006 Krishnan & Davidovitch, 2006 Grewal et al., 2020 Bernhardt et al., 2001 Jackson et al., 1989 Fleming et al., 2016 Wang et al., 2012 Roth & Thrash, 1986 Weiss & Carver, 1994 Marie et al., 2003 Hwang et al., 1994 Otasevic et al., 2006 Ireland et al., 2016
Summary	• although minimising pain is every clinician's objective, it is not possible to eliminate pain despite developments in understanding pain mechanism • pain is subjective and multifactorial • important to inform pt about each phase of treatment along with the pain and discomfort associated with it • when prescribing analgesics, choose the most effective with least possible side effects (check for allergies or asthma) • consider administration of analgesics 1hr prior to seps, band or archwire placement • consider soft, sugar-free chewing gum to ↓ analgesic intake • try to ↓ anxiety	

Recommended reading	Krishnan, 2007; Fleming et al., 2016; Monk et al., 2017; Grewal et al., 2020	
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Periodontal Problems Related to Appliance Wear

Classification	- new classification of periodontal diseases - involves staging and grading	British Society of Periodontology, 2018
Types of problems seen during orthodontic treatment	- gingivitis - gingival recession - gingival hyperplasia - ANUG - localised or molar/incisor presentation of periodontitis - rapidly progressing periodontitis - periodontitis - associated with systemic diseases: phenytoin induced gingival overgrowth, diabetes, neutropenia, leukaemias - burns (from electrothermal debonders)	McComb, 1994 Sheller & Williams, 1996
Aetiology	- multifactorial - gingival and periodontal diseases are influenced by: - bacterial biofilm at the gingival margin (plaque) - host immune and inflammatory responses - environmental factors - gingival and periodontal problems can be induced/exacerbated by: - poor oral hygiene - proximity of appliances to gingival margins - plaque retentive factors, e.g. ledges on brackets - tooth movements, e.g. expansion, proclination - ANUG - rare; smoking and immunosuppression ↑ risks - burns - electrothermal debonders, etchant	Lang & Bartold, 2018 Morris et al., 2017
Incidence	- nearly all FA pt will get gingivitis - rarely progresses to attachment loss - transitional ↑ in periodontal indices, which ↓ after 3mths with no destruction of deep periodontal tissues	Boyd & Baumrind, 1992 Ristic et al., 2007
Short-term effects	↑ plaque accumulation, bleeding on probing and probing pocket depth shortly after placement of FA - FA results in shift in subgingival microbiota - bands more plaque accumulation and gingival inflammation than bonds - adolescents more plaque accumulation and gingival inflammation than adults - gingival enlargement transient resolves within weeks of debond - periodontal pathogens associated with gingival inflammation are significantly reduced by appliance removal	Atack et al., 1996; Naranjo et al., 2006 Naranjo et al., 2006 Alexander, 1991 Boyd & Baurmind, 1992 Sallum et al., 2004; van Gastel et al., 2011
Long-term effects	- no clinically relevant detrimental effects on clinical attachment levels - mean loss of attachment 0.1mm compared with controls, although 10% of pt → significant more destruction than average >1-2mm 10% of orthodontic pts had significant attachment loss (1-2mm) compared with controls, but 50% had no loss ↑ loss of attachment in orthodontic pts with good OH: 0.2-0.3mm compared with 0.1mm in controls - pts showed bone loss (0.25mm) but mainly at Xtn sites ↓ bone support in pts compared with controls - children who received treatment showed ↓ in plaque and gingivitis scores (may be related to behavioural change)	Papageorgiou et al., 2018 Alstad & Zachrisson, 1979 Zachrisson, 1976 Hamp & Johansson, 1982 Zachrisson & Alnaes, 1974 Sjohien & Zachrisson, 1973 Davies et al., 1991

	- orthodontic treatment and fixed retainers associated with ↑ incidence of gingival recession but finding of low clinical significance - fixed retainers seem to be a retention strategy compatible with periodontal health &/or not related to detrimental effects on the periodontium - orthodontic treatment may promote gingival recession and small worsening of periodontal status after treatment	Levin et al., 2008 Arn et al., 2020 Bollen et al., 2008
Bracket type	- self-ligating brackets - no advantage over conventional brackets in periodontal status of mand ant teeth - bond instead of banding molars - Plaque Index was significantly ↓ with Invisalign, but periodontal condition identical with Invisalign and FA	Pandis et al., 2008 Fleming & Johal, 2010 Miethke & Vogt, 2005
Ligation	- O rings versus SS lig - no difference in gingival index, plaque or pocket depths - O rings more prone to bleeding	Turkkahraman et al., 2005
Specific microbiology	General ↑ in all bacterial counts ↑ spirochetes, fusiform bacteria, rods and gram-ve anaerobes Around bands - associated with microbial shift: ↓ cocci and ↑ anaerobic rods, <i>Prevotella intermedia</i>, spirochaetes and motile organisms	Bloom & Brown, 1964 Naranjo et al., 2006 Huser et al., 1990
Adjunct to treatment	Physical - Oral Hygiene Motivation Method (OHMM) - electric toothbrush - professional prophylactic programmes Chemical 0.12% chlorhexidine gluconate ↓ plaque in orthodontic pts 0.2% chlorhexidine gluconate usually recommended	Ay et al., 2007 Yaacob et al., 2014 Huber et al., 1987 Brightman et al., 1991; Anderson et al., 1997
Prevention	- pt selection - good OH and motivated - ensure no active periodontal disease prior to treatment - bonds are better than bands - no difference in periodontal status between post-orthodontic and non-orthodontic pts - gingival surgery - care when using electrothermal debonders	Alexander, 1991 Polson et al., 1988
Periodontal screening	- Basic Periodontal Examination (BPE) 7-11yrs (UR6, UR1, UL6, LL6, LL1 & LR6) codes 0-2 12-17yrs (UR6, UR1, UL6, LL6, LL1 & LR6) all codes 18+ ↑↓ 7-7 & all codes	British Society of Periodontology, 2016
Treatment of periodontally compromised pts	↑ number of adults seeking treatment, many of whom may have some degree of periodontal disease ↓ in perio support, assoc with flaring, extrusion, rotation, spacing and drifting ↑ incisors susceptible - stabilise periodontal condition - possible orthodontic tooth movement required: <i>alignment, space redistribution, intrusion</i> - consent for "black triangles" - bone loss alters position of centre of resistance of teeth and force required to achieve movement - permanent retention - pts satisfactorily treated if a combined orthodontic/periodontal approach is used	Antoun et al., 2017 Boyd & Baurmind, 1989; Eliasson et al., 1982; Steffensen & Storey, 1993 Janson et al., 2011

	- interdisciplinary strategies needed to undertake complex treatment - plaque control is key to prevent deleterious effects of treatment - this is often neglected - consider aesthetic factors during treatment planning, e.g. uneven gingival margins - careful treatment can improve gingival recession, infrabony defects and interdental papilla levels - orthodontic tooth movement towards infrabony defect combined with intrusion and surgical periodontal therapy results in significant clinical attachment gain and R/Gic bone fill - extrusion of non-restorable teeth prior to implant placement is viable alternative to conventional bone augmentation procedures in implant recipient sites - intrusion of teeth improves levels of attachment, stable in long-term - combination of orthodontics with periodontal treatment shown to benefit the periodontal therapy	Rodriguez Flores, 2010 Dersot, 2010 Gkantidis et al., 2010 Cardaropoli, 2009 Corrente et al., 2003 Korayem et al., 2008 Melsen et al., 1989 Boyer et al., 2011
Timing of treatment	- orthodontic treatment should be delayed until periodontal condition is STABLE - pre-treatment targets: -probing depth <5mm -plaque score <15% -bleeding score <15% -cleansable roots and prosthesis -no root caries - periodontology stability varies according to treatment approach; true healing completed at 12mths - ortho to start 3-6 mths after non-surgical treatment - ortho to start 9-12 mths after regenerative surgical procedures - during treatment, OHI, professional cleaning 3mthly, periodontal re-examination every 6-12 mths	Johal & Ide, 1999 Prato & Chambrone, 2020
Interdisciplinary management	- uneven gingival margins - if the probing depth is different consider gingivectomy, if not, evaluate clinical crown lengths to determine whether extrusion of tooth with longer clinical crown and subsequent grinding of its incisal edge is appropriate - if caused by passive eruption of the tooth, the overerupted tooth should be intruded - missing interdental papilla - requires a combination of interproximal reduction, tooth movement and selective addition of composite resin - gingival overgrowth - non-surgical treatment - surgical treatment, e.g. conventional-scalpel, electrosurgery, laser - RCT scalpel gingivectomy and laser more effective in controlling gingival inflammation than non-surgical treatment	Bellemy et al., 2008 Kokich, 1996 Lione et al., 2020
Retention	- permanent retention is vital where ↓ periodontal support present - concern that prolonged retention may pose ↑ risk to the periodontium - syst review: lack of high quality evidence to endorse use of one retainers over another based on their effect on periodontal health	Årtun & Urbye, 1988 Al-Moghrabi et al., 2016 Al-Moghrabi et al., 2016
Recommended reading	Atack et al., 1996; Bollen et al., 2008	

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Incidence & Prevalence	- teeth most commonly affected - upper incisors - most common damage to teeth - enamel fracture (64%) - more common in boys - greatest incidence of incisal damage is accidental 10% of orthodontic new pts have evidence of trauma - traumatized teeth do not receive appropriate treatment Prevalence of accidental trauma 12% in 12yr olds, 10% in 15yr olds (data 2013) - decline in trauma observed in 15yr old boys. 17% in 2003, 11% 2013 - reflection of changing lifestyle Risk Factors 1. OJ - OJ >9mm ↑ trauma to upper incisor by 45% ↑ OJ ↑ risk of damage 35% of 9yr olds have evidence of trauma regardless of OJ values - OJ >6mm ↑ risk of traumatic dental injuries 2. Lip coverage	Nguyen et al., 1999 Pitts et al., 2015 Atack, 1999 Bauss et al., 2004 Chadwick et al., 2006 Pitts et al., 2015 Todd & Dodd, 1985 Arraj et al., 2019 Dewhurst et al., 1998 Schatz et al., 2020 Burden, 1995; Bauss et al., 2008				
Prevention of trauma	- low to moderate quality evidence that providing early treatment for pts with ↑ OJ (2 phase, i.e. functional between 7-11 years and fixed in adolescence) is more effective than providing 1 phase treatment (functional followed by fixed) in adolescence - early 2 phase TB treatment ↓ risk of trauma by 10% when compared to treatment in adolescence; would need to treat 10 pts early to ↓ risk for 1 pt - no differences between early treatment and treatment in adolescence with respect to Sk pattern, Xtn rate or self-esteem	Batista et al., 2018 O'Brien et al., 2003 Batista et al., 2018 O'Brien et al., 2009				
Disadvantages of early treatment	- more attendances ↑ treatment length - poorer final dental occlusion - cost factors - compliance	O'Brien et al., 2009				
Effects of orthodontic treatment on traumatized teeth	<table><tr><td colspan="2">Evidence suggest:</td></tr><tr><td> - transient pulpitis - root damage - root resorption </td><td><i>Normal effects of orthodontic tooth movement more likely in previously traumatized teeth</i></td></tr></table>	Evidence suggest:		- transient pulpitis - root damage - root resorption	<i>Normal effects of orthodontic tooth movement more likely in previously traumatized teeth</i>	Malmgren et al., 1982 Linge & Linge, 1983
Evidence suggest:						
- transient pulpitis - root damage - root resorption	<i>Normal effects of orthodontic tooth movement more likely in previously traumatized teeth</i>					
Risks of orthodontic treatment to previously traumatized teeth	Loss of vitality 7.3% traumatized incisors became non-vital compared with 1.7% non-traumatized teeth (small number study) ↑ risk of loss of vitality of previously traumatized teeth during treatment; risk ↑ the more severe the initial injury Pulpal calcification ↑ risk of teeth showing signs of pulpal obliteration prior to orthodontic becoming non-vital during treatment Root resorption - aetiology multifactorial - incidence in healthy teeth during orthodontic treatment of 1-2mm; previous trauma is a risk factor, if tooth shows signs of resorption before treatment then at ↑ risk - the more severe the initial injury, the ↑ the risk - previous trauma unlikely to be causative factor - root filled teeth - no ↑ risk of root resorption	Brin et al., 1991 Bauss et al., 2009 Bauss et al., 2009 Malmgren et al., 1982; Linge & Linge 1983, 1991; Kennedy et al., 1983 Al-Badri et al., 2002 Weltman et al., 2010 Esteves et al., 2007				

"Observation Periods" recommended prior to start of active treatment	• <i>crown fracture</i> (non-pulpal and pulpal involvement) - 3mths after R/Gic evidence of hard tissue bridge formation • <i>root fracture</i> (depends on type of healing) - 1-2yrs; 1yr in the absence of complications • <i>granulation tissue healing</i> - do not undertake treatment • <i>subluxation and lateral luxation</i> - 3mths • <i>intrusion, extrusion and replantation</i> - 12mths • <i>RCT due to trauma</i> - observation in line with injury • <i>RCT due to root resorption</i> - 12 mths need R/Gic evidence of healing • good summary guidelines	Malmgren et al., 2007 Zachrisson & Jacobsen, 1974 Andreasen et al., 1989 Kindelan et al., 2008 Sandler et al., 2021
Orthodontic protocol for previously traumatized teeth	Pre-treatment assessment • good history taking • observation of dentition • clinical examination - colour, vitality testing, percussion, mobility, infraction lines • R/Gic assessment - 2x LCPA if root # suspected Be wary of false negative results	Duggal et al., 2015
Management and precautions during orthodontic treatment	• informed consent needed • joint care and planning provides best results • avoid excessive pressure - use light, short acting forces (less than 70gms) • avoid moving roots into palatal plate • monitor pulpal health and root resorption during treatment • monitor using trauma grid • R/Gic views taken 6-9mths into treatment • if R/Gic evidence of damage reassess treatment goals	Luther et al., 2005 Atack, 1999 Ten Hoeve & Mulie, 1976 Crawford et al., 1997 Malmgren et al., 2007
Management of teeth traumatized during orthodontic treatment	Summary of guidelines Immediate • full examination including history, R/Gs and vitality tests • placement of composite restorations over exposed dentine improves long term prognosis • displaced, extruded, intruded or replanted teeth can be repositioned with FA using aligning wires, then observed for 12mths • no evidence based guidance on when to restart treatment • permanent RCT filling can be placed to ↓ risk of root fracture, (non-setting CaOH₂ used to ↓ inflammation or encourage apexification) • 6-9mths R/Gic reviews to check for root resorption Long-term • permanent restoration can be placed • routine review 'check ups' by GDP for further signs of pathology • interdisciplinary team planning for best results	Sandler et al., 2021 Andreasen, 2007 Hamilton & Gutman, 1999 Kindelan et al., 2008 Day et al., 2008
Prevention	• recommend use of mouthguard • types: -stock -mouth-formed -custom made • minimal evidence on effectiveness • custom-formed (pressure laminated) recommended probably because pt more likely to wear due to better fit	Salam & Caldwell, 2008; BOS, 2017 Maeda et al., 2009 BOS, 2017
Recommended reading	Atack, 1999; Arraj et al., 2019; Duggal et al., 2015; Batista et al., 2018; Sandler et al., 2021	

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Definition	If treatment is to be of benefit to the pt the advantages it offers should outweigh any possible damage it may cause	Shaw et al., 1991a
Justification for treatment	- low level of evidence for benefits - principle reasons for carrying out orthodontic treatment: - to improve the dento-facial appearance - to correct occlusal relationships - to eliminate malocclusions that could damage the long-term health of the teeth and/or periodontium	Benson et al., 2015 Jawad et al., 2015
Provision of treatment	Assessing orthodontic treatment need 3 elements - normative need - professionally-judged using a standardised clinical index, e.g. IOTN - expressed need - pts with need presenting for treatment - demand - felt need - pts' perception of need Quantification of need 2008/9 NHS epidemiological health survey of 12yr olds demonstrated normative orthodontic treatment need of 30.5-33% Commission factors influencing provision of treatment - eligibility assessed with IOTN - clinical need currently set at IOTN 3.6 or above (see section on Indices) - complexity descriptors - 1, 2, 3a, 3b to determine treatment setting GDP factors influencing provision of treatment - GDP's awareness, training, and attitudes to orthodontics - GDP's diagnostic acuity or experience, e.g. GDP identifying impacted 3's - differences in GDP/pt perception of need, i.e. "GDP induced paranoia", important to supplement clinical measures with pt measures of treatment need - assessment of normative need - GDC standard that GDPs should be competent in carrying out an orthodontic assessment and providing an indication of treatment need - access to advice/support/specialist's opinion, i.e. availability of services - orthodontic training capacity, i.e. orthodontic courses, training GDP's Pt factors influencing treatment demand - influenced by social and cultural factors, e.g. social media - the wish to look attractive, i.e. improving appearance - perceived need/malocclusion, wide variation of normal is regarded as acceptable - gender - females want attractiveness more than males - parental aspirations, i.e. to do the best for one's child - socio-demographic characteristics - ↑ socio-economic groups more likely to seek treatment for child's minor malocclusion than ↓ groups; adult pts from ↑ socio-economic groups more likely to seek treatment - experience of bullying - age - adults seeking orthodontic treatment is ↑; adults more concerned about improving appearance and social acceptance than function	NHS England, 2015 NHS England, 2015 Miguel et al., 2010 Jawad et al., 2015 O'Brien et al., 1998 Shaw, 1981 Tuncer et al., 2015 Seehra et al., 2013 Jawad et al., 2015
Benefits	Function <i>Mastication</i> - evidence equivocal primitive ancestors did not need features of an ideal occlusion as excessive attrition → no cusps	

	• present day refined diet → masticatory efficiency is unrelated to absorption of food • presence of malocclusion ↓ masticatory function • association between orthodontic finishing and balanced activation of temporalis muscles but no effect on chewing efficiency • pts with CI I molars have more occlusal contact than pts with CI II and CI III but may not affect function • pts with hypodontia have more difficulty chewing certain foods <i>Speech</i> - evidence equivocal • 90% of consonants are made in the anterior portion of the oral cavity suggesting dental arch relationships may affect articulation • features of malocclusion are associated with speech production errors; the more severe the malocclusion the more likely a speech error will occur; AOB most likely occlusal trait to impact on sound production • no evidence relating malocclusions to speech discrepancies • no evidence to draw conclusions between orthodontic treatment and/or orthognathic surgery on speech Dental Health <i>TMJ</i> (see section on Temporo-Mandibular Dysfunction) • multifactorial aetiology • evidence that malocclusion causes TMJD disputed <i>Tooth impaction</i> • dentigerous cyst formation, incisor root resorption (3 3 → 2 2 resorption in 48% of cases on CT studies and 12% on plain view) <i>Caries</i> • assumption that dental crowding is a risk factor for caries • no high-quality studies to confirm a causal relationship between crowding and dental caries <i>Periodontal disease</i> - equivocal • misaligned teeth do have more plaque collection than straight teeth, but socio-economic group, gender, tooth side and tooth surface have ↑ influences • in right handers, crowded teeth on left are cleaner than straight teeth on right • weak evidence suggesting association between malocclusion and periodontal disease • evidence that certain malalignment traits are risk factors in periodontal disease progression, e.g. anterior crowding/spacing • ↑ OB/anterior crossbite can cause periodontal trauma; not strictly periodontal disease but can cause significant clinical attachment loss • evidence that orthodontic treatment can improve and stabilise recession; however, no long term problems if oral hygiene is good <i>Trauma</i> • ↑ OJ → ↑ incidence of trauma, especially males • early treatment can ↓ risk of incisor trauma - using a functional appliance: for every 10 cases of ↑ OJ treated → 1 less incidence of trauma than if single phase of orthodontic treatment in adolescence Adjunct to other dental treatment • joint periodontal/restorative/orthognathic cases	Magalhães et al., 2010 Shim et al., 2020 Owens et al., 2002 Laing et al., 2010; Akram et al., 2011 Leavy et al., 2016 Hassan et al., 2007 Benson et al., 2015 Ericson & Kurol, 1987, 2000 Hafez et al., 2012 Davies et al., 1988, 1991 Addy et al., 1990 Bollen, 2008 Alsilaïman et al., 2018 McComb, 1994 Eismann & Prusas, 1990 Pitts et al., 2015 Batista et al., 2018 Proffit et al., 2012
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	- types of movements undertaken: - redistribution of space - intrusion/extrusion - decompensation Appearance and psychological well-being <i>Teasing</i> - teeth were the 4th most common feature that children were teased about - teasing about teeth caused the greatest distress, however, children were also teased about wearing braces - children with ↑ treatment need experience more bullying and lower self-esteem - bullying ↓ by 78% post-treatment - certain occlusal traits such as ↑ OJ and spacing appear to have some negative impact on children and their families <i>Stereotyping</i> - rearranged facial photographs of 5 dental arrangements and asked individuals to judge photographs: - CI I relationships → better assessor grading, but level of background facial attractiveness had ↑ influence - in life, friendship was not influenced by extremes of facial or dental attractiveness - observers attribute more favourable personality traits to fictitious persons with regular dentitions - more ideal smiles considered more intelligent and have ↑ chance of finding job <i>Self esteem</i> - those with low self esteem overestimate severity of their malocclusion but low self esteem persists after treatment - no evidence that malocclusion causes poor self esteem in long-term, but Danish studies have shown that adults with severe malocclusion have ↑ memories of being teased than those who don't have a severe malocclusion, i.e. might impair their quality of life - systematic review demonstrated presence of a malocclusion has a negative effect on quality of life (emotional and social)	Benson et al., 2015 Shaw et al., 1980 Shaw et al., 1980 DiBaise & Sandler, 2001; Seehra et al., 2011 Seehra et al., 2013 Johal et al., 2007 Shaw et al., 1985 Klages et al., 2004 Pithon et al., 2014 Kenealy et al., 1989 Lazaridou-Terzoudi et al., 2003 Dimberg et al., 2015
Risks	TMD (see section on Temporo-Mandibular Dysfunction) - weak evidence exists Iatrogenic damage of treatment - risks are present in short, medium and long-term (see sections on Iatrogenic Damage, Intra- and Extra-Oral Damage and Systemic Effects of Treatment) Stability - overall evidence demonstrates that stability of treatment cannot be guaranteed (see section on Stability) Profile - some maintain that extracting teeth during treatment produces a 'flattened' or 'dished-in' profile but evidence supports view that incisor retraction or Xtn therapy does not produce a clinically significant change in profile - retrospective study - 2mm difference in profile long-term between Xtn/non-Xtn cases, although the effect is minimal be wary if nasolabial angle is obtuse (>110°) - borderline Xtn cases treated with 4 premolar Xtns will exhibit lip retraction (1.5mm ↑ lip, 2mm ↓ lip) - systematic review - Xtns seem to affect pt profile; however, studies are heterogenous and no consistent predictions to pt profiles can be made	Luppanapornlarp & Johnston, 1993 Paquette et al., 1992 Bravo, 1994 Paquette et al., 1992 Kouli et al., 2018

	- upper lip thickness not associated with amount of lip retraction Discontinuation of treatment "perhaps the greatest risk in orthodontic treatment is that of partial or total failure in accomplishing a worthwhile, lasting change" - discontinuation rate - 12.8% in UK specialist practice - factors influencing failure: - gender - greater adherence to tx from females - age - younger pts ↑ risk of failure - IOTN - higher failure in cases with IOTN 5 - socio-economic status - appliance - ↑ failure with functionals>removal>fixed - history of failed appointments - co-operation - use of 'messenger apps' can ↓ number of missed appointments and overall treatment time - early debonds have a lower PAR reduction - evidence suggest that qualified orthodontic practitioners → better results than non-qualified GDP's; may be related to appliance choice as GDPs used more URAs	Konstantonis et al., 2018 Alkadhi et al., 2019 Shaw et al., 1991b McDougall et al., 2017 Li et al., 2016 McMullan, 2005 Richmond, 1989
Summary	- disadvantages of malocclusion with respect to dental health and function are modest - in elderly populations, proportion of subjects with severe malocclusions is not significantly less than in matched sample of children therefore longevity is not affected - apart from trauma, there is an absence of evidence on effects of malocclusion on oral health and the impact of orthodontic treatment on oral health - research lacks consistency due to diverse range of outcome measures, a core bespoke outcome set has been suggested to allow meaningful comparisons	Shaw et al., 1991a,b,c Macey et al., 2020 Tsichlaki et al., 2020
Individual risk - benefit appraisal	- pt perceptions of risk/benefit is improved where orthodontic need on aesthetic grounds was ↑ orthodontic risk - benefit analysis → BALANCING ACT - pts with most to gain are those with severe malocclusions who are treated by experts - mild occlusions have the most to lose with little to gain	McComb et al., 1996 Richmond, 1989
Recommended reading	Shaw et al., 1991a,b,c; Benson et al., 2015	

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Medicolegal Aspects of Practice

Consultation with a dental indemnity organisation is advised if the reader has any medicolegal concerns. This book is not intended to act as a legal reference, and the authors claim no responsibility for the legal implications of issues arising.

Ethical responsibilities	Code of practice Practitioners must abide by profession's ethical guidance as described in 'Standards for Dental Professionals' published by GDC 1. put pts' interests first 2. communicate effectively with pts 3. obtain valid consent 4. maintain and protect pts' information 5. have a clear and effective complaints procedure 6. work with colleagues in a way that is in pts' best interests 7. maintain, develop and work within your professional knowledge and skills 8. raise concerns if pts are at risk 9. make sure your personal behaviour maintains pts' confidence in you and the dental profession	GDC, 2013
	Duty of candour • professional responsibility to be open and honest with pts when something has or may have gone wrong with their treatment/care • legal requirement since 2014 • must tell pt/family when something goes wrong • apologise to pt/family • offer appropriate remedy/support to put matters right if possible • explain fully to pt/family, short and long-term effects of what has happened	GDC, 2016 BOS, 2017
Communication	• purpose - link pts needs and preferences with the clinician's knowledge, skills and performance to accomplish goals • should be pt centred • good communication combined with trustworthiness and truthfulness builds a good relationship and rapport	Chauca, 2018
Complaints	• poor communication is the major predisposing factor that influences whether a pt will complain • pts should be made aware of practice complaints procedures/Patient Advice and Liaison Service (PALS) • GDC Standards 5.1 explains how to deal with complaints • NHS complaints acknowledge within 3 working days	BOS, 2016 GDC, 2013 NHS England, 2017
Consent	Classification • implied, e.g. attending the surgery • expressed, e.g. verbal or written • consent is an ongoing process	Campbell et al., 2008 Williams et al., 2015 BOS, 2015a
Valid consent	Pt must: • be capable of making that decision (competent) • be given enough information to have understanding of: - treatment options, including no treatment - pt commitment - benefits of treatment - limitations of treatment - risks of treatment/no treatment- retention • written consent is an adjunct to show willingness to achieve informed consent in litigation cases	Proffit & Ackerman, 1995
Risks	See sections on Intra-oral and Extra oral Iatrogenic Damage	

Age and consent	Aged 18 and over - assumed to be a competent adult capable of consenting Aged 16 and 17 - pt can consent to treatment, but a person with parental responsibility can also consent - if a child aged 16 or 17 consents to treatment, consent cannot be withdrawn by the person with parental responsibility Younger than 16 - current practice usually involves parental consent - if pt has sufficient understanding of proposed treatment and all related issues may consent (Gillick versus West Norfolk and Wisbech Health Authority 1985) - although an unaccompanied child may be competent to consent, it is wise to encourage the child to involve the parents - parental responsibility rests with both parents, provided they are named on the birth certificate and regardless of whether they are married	BOS, 2015a Family Law Reform Act, 1969 Williams et al., 2015 BOS, 2015a
Negligence	Definition - lack of attention, care or concern - breach of professional duty In order to demonstrate negligence a pt must prove - there was a legal duty of care - a breach of that duty - resultant loss or damage - damage was foreseeable Issue of informed consent - how much did the pt understand and remember? - were the risks fully explained? - were they given time to ask questions?	Doyal & Cannell, 1995 Morris et al., 2019
Bolam Test	Historical now Montgomery - previously used in England to determine what should be disclosed to a pt as part of informed consent to avoid liability in negligence - based on the principle that one is not guilty of negligence if they have acted in accordance with a practice accepted as proper by a professional body of opinion	Morris et al., 2019
Montgomery Test	- duty of care to warn of all material risks - materiality defined as whether "a reasonable person in the pt's position would be likely to attach significance to the risk" - doctors need to ensure that the pt is aware of any material risks involved in any recommended treatment, and of any reasonable alternative or variant treatments	Chan et al., 2017
Clinical guidelines	increasingly used in courts to provide evidence of proper standard of care	Warren-Jones, 1999
Examples	National Institute of Clinical Excellence (NICE) e.g. removal of wisdom teeth RCS England e.g. management of the unerupted central incisor BOS - clinical guidelines, e.g. management of inhaled or ingested foreign body, orthodontic R/Gic guidelines - ethical guidelines, e.g. child protection	
Minimum data set	- notes should record: personal details, clinical assessment, diagnosis, aims and objectives - treatment plan - consent	BOS, 2015b

	- record of treatment - treatment outcome - CLP has specific data set (see section on Clefts) - BOS/BAOMS has specific minimum data set Retention of records - adult - 10 yrs after conclusion of treatment - child - until 25th birthday or 26th if an entry was made when the pt was 17 at the conclusion of treatment	
Recommended practice	- promote trust - communicate well - records according to minimum data set - SMs - pre and post treatment - R/Gs - photographs - consent - verbal, with written consent as an adjunct - in-house complaints procedure	BOS, 2014 BOS, 2015b
Confidentiality	- respect confidentiality unless pt gives permission to disclose personal information - professional, ethical and contractual obligation - important duty but not absolute, disclose information if required by law, in the public interest, pt consents - seek consent if able prior to disclosure if required - confidentiality applies to all health care team members - see GDC Standards	BOS, 2015b GDC, 2013
General Data Protection Regulations 2018	- supersedes the legislation of the Data Protection Act - organisations are accountable in the way that they collect, use, store and dispose of personal information 6 basic principles - pt legally able to access notes with no charge	Hemmings & Noar, 2018
Digital Records	- all practices should be registered with the Information Commission whether digital or paper records are used - digital photography is regulated under copyright law, therefore person (or employer, i.e. NHS Trust) who takes image owns the rights to this; however pts have the right to access upon request - need to ensure secure storage arrangements	BOS, 2015b
Continuing Professional Development (CPD)	- GDC guidance, by law required to - achieve a minimum of 10 hours verifiable CPD/2yrs - have minimum of verifiable CPD: 100 hours in 5yrs - have a PDP - log CPD - declare CPD annually	GDC, 2018
Advertising	- GDC Standards for Dental Professionals regulates this area - all information regarding dental services should be legal, decent, honest and truthful - advertising should not be used to recommend a specific product or technique, or make claims which could be misleading - advertising also falls under the jurisdiction of Committee of Advertising Practice, Advertising Standards Authority, Office of Fair Trading	GDC, 2011 BOS, 2014
Websites	- governed by Electronic Commerce Regulations 2002 - following are requirements: name, professional qualification and country qualification is derived, address and contact details of practice, GDC number, link to GDC website, clear date of last update	GDC, 2011
NHS versus Private	if a pt qualifies for NHS treatment this should be offered primarily	BOS, 2014

	• mixing NHS and private care should be avoided • where private treatment is offered as an alternative the differences and rationale must be fully explained • private treatment may be offered on the basis of convenience or more aesthetic appliances or if the pt has a low index of treatment need • practitioners must not make inappropriate claims about differences in care/result between NHS and private treatment	
Bribery Act, 2010	• bribery is defined as the 'offering or acceptance of inducements designed to influence official action or decision-making'; includes offering a bribe, being bribed, a corporate offence of failure to prevent bribery • this act reforms the criminal law of bribery making it easier to tackle this offence in private and public sectors including the NHS • organisations will have to show they have "adequate procedures" to prevent this, such as declaration of gifts • avoid asking for/accepting payments, gifts or hospitality for referrals	GDC, 2020
Recommended reading	BOS, 2014; Ireland et al., 2015	
Useful Websites	GDC - General Dental Council - www.gdc-uk.org Department of Health website - www.dh.gov.uk GMC - General Medical Council - www.gmc-uk.org RCS England Guidelines - www.rcseng.ac.uk/fds/clinical_guidelines	

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Materials

Friction

Brackets

Archwires

Adhesives and Cements

Force Delivery Systems

Friction

Definition	A force that retards or resists the relative motion of two objects in contact, and its direction is tangential to the common boundary of the 2 surfaces in contact	Drescher et al., 1989
Classical laws of friction	- proportional to force normally acting on the contact - independent of the area of contact - independent of the sliding velocity Friction (FR) = Force (F) x Coefficient of Friction (μ)	Tidy, 1989
Friction and orthodontics	Definitions: Static friction: smallest amount of force required to initiate sliding between objects Kinetic friction: amount of force resisting sliding once moving Static friction is more important in orthodontics as teeth most probably 'walk' along the archwire with small tipping and uprighting movements rather than slide; influenced by: - nature of the contacting surface but is independent of apparent area of contact, this is due to the interlocking of surface irregularities (asperities) - coefficient of friction (μ) is proportional to shear strengths of these junctions and inversely proportional to yield strength of material - extent to which asperities on the harder material plough into the surface of the softer material Total frictional resistance is the sum of: - force necessary to shear all junctions - resistance caused by interlocking roughness 'ploughing' component of the total frictional forces In orthodontics: Resistance to sliding = Friction + Binding + Notching (<i>Binding</i> is different materials 'catching' against each other; <i>Notching</i> is the material deforming and gouging out areas)	Omana et al., 1992a Omana et al., 1992b, Burrow, 2009 Kusy & Whitley, 1997
Affected by:	Brackets - material, dimensions - ceramic > friction than metal - ceramic with metal slot same friction as metal, materials in contact are similar - narrow brackets allow $\uparrow$ tipping than wide brackets, therefore have $\uparrow$ critical angle and more binding, i.e. $\uparrow$ resistance to sliding - wire type and method of ligation have more effect on friction than bracket material in buccal segments Wires - material - β titanium > friction than NiTi > friction than SS - shape - rectangular $\rightarrow$ > friction than round, although within each geometry, dimensions have little effect on friction; kinks in wire may $\uparrow$ binding - torque - $\uparrow$ friction - surface topography of each material - ion-implantation of archwire supposed to $\downarrow$ friction in vitro, but studies have demonstrated no effect in vivo Ligation - material - variable effects - SS ligatures $\rightarrow$ $\downarrow$ friction than elastomeric ligatures - elastomeric ligatures $\rightarrow$ 60-70% more friction than SS - teflon coated ligatures may $\downarrow$ friction however layer may come off	Angolkar et al., 1990 Tidy, 1989 Thorstenson & Kusy, 2003 Tidy, 1989 Andreasen & Quevedo, 1970 Ireland et al., 1991 Angolkar et al., 1990 Frank & Nikolai, 1980 Sims et al., 1993 Ryan et al., 1997; Kula et al., 1998 Shivapuja & Berger, 1994 Edwards et al., 1995

	• 'Super Slick' modules ↑ friction than conventional elastomeric modules • forces - tighter ligation ↑ friction • pre-stretched ligatures ↓ friction • self-ligating brackets have less friction than ligated brackets, but tip and torque ↓ this benefit • number of attachments through which the wire passes - ↑ attachment ↑ friction • composite ligatures - may ↓ friction Type of tooth movement • tipping or bodily movement Other factors • effects of saliva equivocal • dynamic environment due to oral functions will mean forces on appliance producing motion at bracket-archwire interface, this will lead to zero contact for minute periods therefore overall effect of friction is ↓ • jiggling effect overcomes some frictional force → ↑ movement • vibration induced by mastication did not eliminate friction	Griffiths et al., 2005 Hain et al., 2003 Sims et al., 1993 Taylor & Ison, 1996 Sims et al., 1994 McKamey & Kusy, 1999 Kusy et al., 1991 Braun et al., 1999 O'Reilly et al., 1999 Iwasaki et al., 2003
Note	• lab studies of resistance to sliding may not take critical angle and wire deflection into account	
Recommended reading	Tidy, 1989; Braun et al., 1999; Burrow, 2009	

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Classification	• material type - metal, ceramic, polycarbonate, polyurethane • morphology - e.g. siamese, mini-twin, single-wing, self-ligating, tip-edge • slot size - 0.018" x 0.028" - lighter forces with 3-D control - 0.022" x 0.028" - allows lighter forces in early stages of treatment due to slop; larger dimension wire = ↑ stiffness, good for arch co-ordination and sliding mechanics - 0.022" x 0.030" eases tying in of auxiliary archwires/piggybacks	
Metal brackets	Types • cast (soft) - may distort on debonding or in deep bite cases close down ↓ slot size • milled (hard) • metal injection moulded (MIM) • sintered Composition • austenitic SS is given an AISI number (American Iron and Steel Institute) • low numbers have little additional alloy metal and are soft • most brackets are AISI 304 milled • AISI 304 composition: Fe 71%, Ni 8%, Cr 18%, C<0.2% • A-company brackets are AISI 316 cast • AISI 316 is too hard to be milled • problem with nickel allergy • titanium, comparable to SS; more biocompatible as nickel is eliminated • cobalt chromium	Matasa, 1992 BOS, 2012
Bases	Types • perforated - obsolete • mesh - fine or coarse, fine mesh give highest bond strengths (single, 2 and 3 ply available) • microlok - spherical photoetching • Dynalok - undercut channels • metal/ceramic bases • polymer coated, e.g. Primekote (TP) Bond strength • bracket base area and bond strength have no direct relationship • vary with different bracket bases	Reynolds, 1981 Wang et al., 2004
Recycling process	• <i>Esmadent</i> - heat then cold solvent, ultrasonic and then electropolish • <i>Orthocycle</i> - solvent and high frequency vibrations then heating for sterilisation, no electropolish	
Effects of recycling	• slot size - negligible change • mesh brackets - ↓ bond strength • Dynalok - ↑ bond strength due to rounding of undercuts • metallurgy - may have adverse changes, e.g. corrosion • ethics and finance - UK orthodontists do not routinely recycle brackets due to ethical issues, safety and financial considerations	Coley-Smith & Rock, 1997; BOS, 2011
Bracket configurations	Edgewise and Straightwire • solid - rarely used • siamese - better rotational control	

	- rotation - Steiner, Lewis, Alexander - single wing, e.g. Attract - poor rotational control - self-ligating, e.g. Speed, In-Ovation, Smartclip, Damon - vertical slots - useful for uprighting and rotation springs, locking pins or hooks (Begg) - bracket slot height - 022" or 018" or mixed system, e.g. torque control with 020" labially and 022" buccally - no difference in treatment outcomes demonstrated with different slot sizes used - bracket slot depth - 028" but some brackets are deeper - molar hooks and power arms - plaque/food trap and may distort - molar tubes usually convertible on first molars, may be single, double or triple with/without HG tubes - premolar bracket bases gingivally off set - 20% ↓ of bond failure in lower 2nd premolars from occlusal interferences	Yassir et al., 2019a,b Swartz, 1994; Tidy & Coley-Smith, 1998																																																																																																														
Prescriptions	- Andrews original values were NOT taken from his study - if he did not agree with the figures from the models he modified them - Roth prescription has more tip and torque in the anterior region; in-out measurements are all similar - Straight wire brackets remove 3 aspects of wire bending: <i>in - out</i> <i>tip</i> <i>torque</i> 1st order 2nd order 3rd order Tip° <table><tr><td>Upper MBT</td><td>4</td><td>8</td><td>8</td><td>0</td><td>0</td><td>5</td><td>5</td></tr><tr><td>Roth</td><td>5</td><td>9</td><td>11</td><td>0</td><td>0</td><td>0</td><td>0</td></tr><tr><td>Andrews</td><td>5</td><td>9</td><td>11</td><td>2</td><td>2</td><td>5</td><td>5</td></tr><tr><td>TEETH</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td></tr></table> Lower Andrews <table><tr><td>2</td><td>2</td><td>5</td><td>2</td><td>2</td><td>2</td><td>2</td></tr><tr><td>Roth</td><td>0</td><td>0</td><td>6</td><td>0</td><td>0</td><td>-1</td><td>-1</td></tr><tr><td>MBT</td><td>0</td><td>0</td><td>3</td><td>2</td><td>2</td><td>2</td><td>2</td></tr></table> Torque° <table><tr><td>Upper MBT</td><td>17</td><td>10</td><td>-7</td><td>-7</td><td>-7</td><td>-14</td><td>-14</td></tr><tr><td>Roth</td><td>12</td><td>8</td><td>0</td><td>-7</td><td>-7</td><td>-14</td><td>-14</td></tr><tr><td>Andrews</td><td>7</td><td>3</td><td>-7</td><td>-7</td><td>-7</td><td>-9</td><td>-9</td></tr><tr><td>TEETH</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td></tr></table> Lower Andrews <table><tr><td>-1</td><td>-1</td><td>-11</td><td>-17</td><td>-22</td><td>-30</td><td>-30</td></tr><tr><td>Roth</td><td>-1</td><td>-1</td><td>-11</td><td>-17</td><td>-22</td><td>-30</td><td>-30</td></tr><tr><td>MBT</td><td>-6</td><td>-6</td><td>-6</td><td>-12</td><td>-17</td><td>-20</td><td>-10</td></tr></table> - Race specific prescription - Ormco produces Ortho AP (Asian Prescription) for their Japanese market - slot size and shape varies from that advertised due to variations in the manufacturing processes	Upper MBT	4	8	8	0	0	5	5	Roth	5	9	11	0	0	0	0	Andrews	5	9	11	2	2	5	5	TEETH	1	2	3	4	5	6	7	2	2	5	2	2	2	2	Roth	0	0	6	0	0	-1	-1	MBT	0	0	3	2	2	2	2	Upper MBT	17	10	-7	-7	-7	-14	-14	Roth	12	8	0	-7	-7	-14	-14	Andrews	7	3	-7	-7	-7	-9	-9	TEETH	1	2	3	4	5	6	7	-1	-1	-11	-17	-22	-30	-30	Roth	-1	-1	-11	-17	-22	-30	-30	MBT	-6	-6	-6	-12	-17	-20	-10	Andrews, 1972 Brown et al., 2015
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Useful bracket placement changes	- palatally placed lateral incisor - invert bracket reverses torque (labial root as opposed to palatal root) - moving canines into lateral position - invert bracket to give palatal root torque (which is normal for lateral incisors) - CI III cases: - reverse lower canine sides (right and left) which reverses tip but not torque (i.e. canines distally angulated rather than mesially) - invert upper incisor brackets in surgical cases where proclination needs to be reversed - use Begg bracket for palatally misplaced canines	Thickett et al., 2007																																																																																																														
Self-ligating Brackets	Advantages - full archwire engagement - shorter overall treatment time (4-6mths)	Harradine, 2001																																																																																																														

	• ↓ chairside assistance required • ↓ chairside time required • ↓ number of appointments • improved infection control • ↓ friction Disadvantages • takes practice! • clips fracturing/opening between appointments • no partial ligation • wire sliding round • cost • aesthetics, although improving with full ceramic options • no evidence of faster alignment or space closure compared with conventional Siamese brackets	Turnbull & Birnie, 2007 Eberling et al., 2001 Thomas et al., 1998; Pizzoni et al., 1998 Songra et al., 2014
Aesthetic Brackets		Russell, 2005
Lingual	Advantages • aesthetics • easier bite opening and arch expansion • no labial decalcification Disadvantages • difficult access • small interbracket span • trauma to soft tissues • food collection • cost	Wiechmann & Nesbit, 2007
Plastic brackets	• initially constructed from acrylic, later polycarbonate and polyurethane metal reinforced slots • problems include staining, lack of strength (debonding/fractures), poor abrasion resistance and permanent deformation (creep) ↓ torque • reinforced with ceramic/fibreglass to improve performance but problems remain with torque	
Ceramic brackets	Definition • ceramics are non-metallic materials which are first shaped and then hardened by heat Types • polycrystalline, e.g. 3MTranscend, 3MClarity • monocrystalline, e.g. Inspire Ice • metal reinforced polycrystalline, e.g. 3MClarity • others, e.g. zirconia brackets - no longer used Features • orthodontic ceramics are made of alumina or zirconia • all ceramics are harder than SS	
Polycrystalline e.g. 3M Clarity, In-Ovation C	• opaque • made by injection moulding of alumina • lots of crystals with imperfections at grain boundaries, more prone to fracture	
Monocrystalline e.g. Radiance Plus, Inspire Ice	• machined from synthetic sapphire • heat treated to relieve stress • clear	
Zirconia	• opaque • poor aesthetics • similar frictional properties to alumina brackets • no longer used	Keith & Kusy, 1994
Chemical Retention	Vinyl silane coupling • initially most had this now use mechanical base retention • some use polymer pad between tooth and bracket, e.g. InVu & ClearVu brackets (TP Orthodontics)	

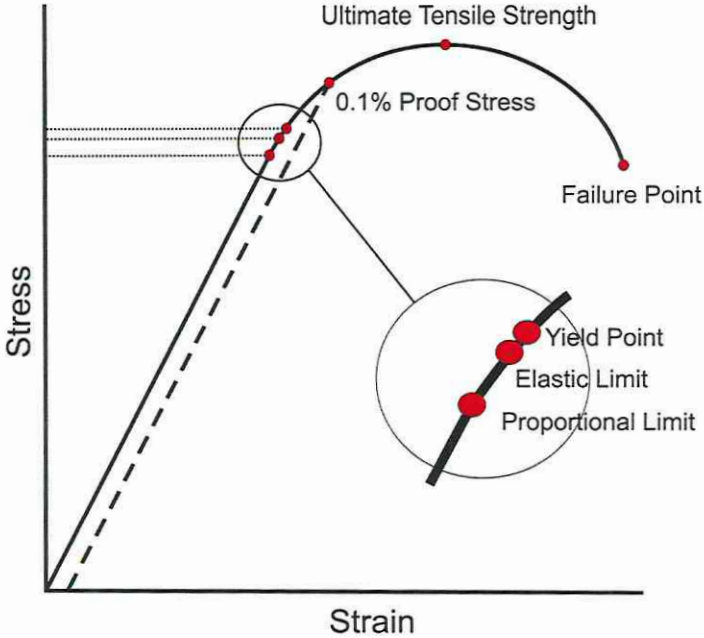
	• bond strength greatest between bracket and composite, therefore enamel fracture more likely	
To ↓ bond strength and risk of enamel damage at debond	• mechanical retention - grooves etc • ↓ silane coupling • use polymer pad between tooth and bracket, e.g. InVu & ClearVu brackets (TP Orthodontics) • careful selection of bonding agent, e.g. use weaker resin • modify etch (15 seconds - weaker bond than 60 seconds) • use ceramic brackets with notched prestressed bases (3MClarity) • bond with Resin Modified Glass Ionomer Cement	Abdullah & Rock, 1996 Larmour et al., 1998
Problems with ceramic brackets	Friction • ↑ frictional resistance to sliding mechanic Enamel wear • avoid in deep OB cases • use bite plane, bond gingivally or use elastomeric ligature with an occlusal guard (3M Unitek) • ↑ risk of enamel trauma when debonding Bracket fracture • fracture of tie-wings • fracture of brackets on debond • if inhaled not radio-opaque	Angolkar et al., 1990 Swartz, 1988
Friction (see section on Friction)	• ↑ problem with ceramic brackets • rectangular archwires produce ↑ friction than round wires • NiTi and TMA produce more friction than SS • may require closing loops rather than sliding mechanics	Tidy, 1989
Reducing problems	Reducing bracket fracture in use: Careful technique such as: • care when applying torquing force, e.g. use rectangular NiTi/TMA before SS • careful ligation, avoid scratching brackets with ligatures → fracture of wings • use elastomeric modules • stress relaxing composite ligatures Reducing enamel fracture avoid: • periodontally involved teeth • root treated teeth • large restorations • sudden impact or torsion • lower incisors (thin labial enamel) • small teeth • cracked enamel Reducing friction: • do not use on premolar teeth • use brackets with SS slots (3MClarity)	KcKamey & Kusy, 1999
Debonding	• use safety glasses • trim composite flash around brackets before debonding • use manufacturers tools • electrothermal debonding pulpal damage possible • air rotor and diamond bur • laser debonding • chemical (peppermint oil - plasticises composite) • ultrasonics • some manufactures recommend specific debonding pliers	Bishara & Trulove, 1990 Winchester et al., 1992 Stewart et al., 2014 Stewart et al., 2014
Other aesthetic brackets	Plastic brackets (polycarbonate) • deteriorate rapidly and stain	

	• 'creep' reep under constant load and therefore loss of torque control • low abrasion resistance and so tie wings wear out in clinical use Metal and ceramic reinforced plastic • better than plastic alone - less creep on torqueing	
Composite	• made from thermoplastic filled polyurethane • available with metal slot Advantages • ↓ staining/discolouration than polycarbonate • ↓ enamel wear than ceramic brackets Disadvantages • low abrasion resistance and so tie wings wear out in clinical use • 'creep' under constant load and therefore loss of torque control	
Recommended reading	Stewart et al., 2014	

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Classification	- material - SS, NiTi, TMA (β-titanium), titanium niobium, cobalt-chromium, polymeric, fibre reinforced composite - cross-sectional shape - round, square, rectangular, hybrid - size - archform type	
Properties	Stress - Strain curve - wire under tension  Stiffness - this is flexural rigidity = EI, where E is Young's modulus of elasticity ($E = \text{stress}/\text{strain}$) and I is the second moment of inertia ($\frac{1}{4}\pi r^4$ for a round wire) - stiffness $\propto E$, conversely springiness $\propto 1/E$ - high in SS and low in NiTi Modulus of resilience (energy storage capacity) - area under the stress/strain curve to the proportional limit - it is a combination of strength and springiness - low in SS but high in NiTi Elastic limit - occurs just beyond the proportional limit; linear elasticity is not observed between these 2 points - when the stress is removed the wire returns to its original shape Yield Strength/Yield point - stress at which plastic deformation occurs - difficult to define so often measured as the point at which deformation of 0.1% occurs (proof stress) Ultimate tensile strength (UTS) - point at which there is $\uparrow$ of strain without an $\uparrow$ of stress Range - distance wire behaves elastically before it deforms permanently - measured from 0.1% point to yield point along x-axis Strength - stiffness multiplied by range Work hardening - wire strained beyond elastic limit $\rightarrow$ plastic deformation; stress returns to zero but permanent set in the wire	

	- subsequent reloading → effect of raising elastic limit and UTS, but distance between these points ↓ → less ductile Formability - the amount of permanent deformation that can occur without fracture (Yield point-fracture point) - capacity of the material to absorb energy while undergoing elastic deformation (area under curve)	
Increasing cross section of wire	- springiness is altered to the 4th power - strength is altered to the 3rd power - range is affected proportionally	
Increasing length of wire	- springiness is altered to the 3rd power - strength is affected proportionally - range is affected as a square	
Ideal/desired properties of an archwire	- constant force over wide arc of deflection - strength - to withstand deformation - high recoverable elastic strain → ↑ wire working time and therefore time of action - high resilience - energy for tooth movement - biocompatible and environmentally stable - friction free - formable - so wire can be formed (shaped) - joinable (weld/solder) - low cost - aesthetic - corrosion resistant No single wire has all these properties hence several wire types exist	Proffit et al., 2012
Stainless Steel		
Composition	71% Fe, 18% Cr, 8% Ni, <0.2% C 18-8 SS (Cr:Ni) Cr → corrosion resistance, Ni → ↑ ductility - austenitic form mainly used in orthodontics - carbon, interstitial hardening and cold working contribute to high yield strength and modulus of elasticity - good stiffness but poor springback, therefore ↑ length alters springiness more than strength Annealing - softens wires, e.g. ligature wires Cold Working - hardens wires, e.g. Wilcox "regular", "special" and "special plus" Yield strength is ↑ at the expense of formability because the distance between the yield point and UTS is ↓ "special" wires are more difficult to bend as they are more work hardened	Kapila & Sachdeva, 1989; Tidy, 1989
Properties	- large modulus of elasticity/high stiffness, advantage in resisting deformation by extra and intra-oral forces but disadvantage in aligning displaced teeth - low springback - low stored energy compared with TMA/NiTi, SS produces ↑ forces that dissipate over shorter periods of time therefore require more frequent activations - joinability good, can solder hooks - corrosion resistance due to chromium when exposed to air oxidizes and protects metal (passive layer) - surface friction low - space closure good due to stiffness and low surface friction	
Types of multistrand SS wires	co-axial - central SS wire with other wires twisted around multistrand wires - 3 SS wires twisted together	

	- combining many thin wires will $\uparrow$ the strength but $\downarrow$ the springiness - very flexible and low cost	Kusy & Stevens, 1987
Nickel Titanium (NiTi)		
Alloys and relevant terms	Shape Memory - ability of wire to deform and then return to its original shape by a mechanical (stress induced) or heat stimulus (thermally activated) Austenitic - high temperature metallurgical phase with a body centred structure Martensitic - low temperature metallurgical phase with an hexagonal structure Active Alloy - one where shape memory can be mechanically or thermally induced Stabilized Alloy - work hardening during processing some wire deformation occurs and this suppresses the shape memory Classification - martensitic stable - austenitic active* - martensitic active* *Phase transformation occurs in response to temperature change and/or stress Superelasticity - change from austenitic to martensitic phase but the $\uparrow$ in strain is not accompanied by an $\uparrow$ in stress - the material behaves elastically in both phases - conventional NiTi mainly in martensitic phase	Waters, 1992 Miura et al., 1986 Kapila et al., 1991, 1992; Kusy, 1997
Composition	52% Ni, 43% Ti, 3% Co	
Types	Nitinol (Martensitic Stable) - good springback useful where large deflections with low forces required; $\frac{1}{6}$th force of SS - greater springback and larger recoverable energy than SS or β-Titanium thus fewer activations necessary - use of rectangular wire achieves simultaneous levelling, torque, and corrections of rotations - does not have superelastic properties or shape memory - friction $\uparrow$ than SS but $\downarrow$ than TMA - low stiffness - cannot be welded/soldered - can recycle with no appreciable loss of properties Superelastic NiTi (Austenitic Active)	Miura et al., 1986; Kusy, 1997; Santoro et al., 2001a,b

	• superelasticity due to phase transformation from body-centred cubic (BCC) austenitic form to hexagonal close packed (HCP) martensitic form of NiTi when stress reaches a certain level during activation - production of SIM (stress-induced martensite) • reverse occurs on deactivation • loading curve (a to b) has its conversion at a higher level of stress than unloading curve (c to d) - see graph • definite amount of stress in spite of changes in strain • can return to original shape after distortion (shape-memory) • superelastic wires need to be deflected at least 2mm to exhibit plateau transformation Thermoelastic NiTi (Martensitic Active Alloys), e.g. Sentalloy • predominantly martensitic at room temperature • thermally activated shape memory • thermal activation can be set at different temperatures (Temperature Transition Range: TTR) • martensite has ¼ the initial stiffness of austenite • once fully transformed into austenite, stress-strain curve behaves the same as any other alloy, e.g. SS Copper NiTi • Cu ↑ strength • ↓ hysteresis • precision setting of TTR - Co added to lower TTR to oral temperature Historical context of NiTi wires: Chinese NiTi • springback to be 1.6x that of Nitinol • behaviour superior to Nitinol for alignment in vitro but clinically Chinese NiTi fracture more easily Japanese NiTi (e.g. Sentinol) • by using the appropriate heat treatment the manufacturer is able to offer Japanese NiTi in 3 different forces (light/medium/heavy) for individual wire sizes Ion Implantation • NiTi wire is implanted with nitrogen	Santoro et al., 2001a,b Santoro et al., 2001a,b Burstone & Morton, 1985 Miura et al., 1988a,b & 1990 Kusy, 1997
Colbat-Chromium (Elgiloy)		
Composition	• 40% Co, 20% Cr, 15% Ni, 15% Fe, 7% Mo, 2% Mn • types of Elgiloy: Blue (soft and easy to bend); Yellow (ductile); Green (semi resilient); Red (resilient) • Elgiloy is soft and formable but hardened and strengthened by heat treatment (at 480°) • precipitation hardening	Kapila & Sachdeva, 1989
Properties	• smaller springback than SS unless heat treated • ↑ resistance to fatigue/distortion than SS • high modulus of elasticity • good formability • caution when soldering as annealing → loss in yield strength • larger frictional forces than SS	
TMA (β-Titanium)		
Composition	• 79% Ti, 11% Mo, 6% Zn, 4% Sn	
Properties	• modulus of elasticity less than SS but twice that of nitinol • superior springback to SS • formability good • joinability - can weld but not solder • corrosion resistance similar to SS/Co-Cr	Kapila & Sachdeva, 1989

	• ↑ friction than SS/Co-Cr • high cost • used as finishing wires	
Aesthetic wires	• coated metallic aesthetic archwires • coating takes up space and therefore the metallic wire diameter is less • some rectangular metallic wires only coated on the labial surface so that less affect on metallic wire dimensions • good initial appearance but coating takes up space therefore wire size restricted, and coating wears off quickly • polymeric aesthetic archwires - poor performance clinically • fibre-reinforced composite archwires - poor performance clinically and very expensive	Shah et al., 2011
Aligning archwires	• insufficient data to make recommendations regarding most effective archwire for alignment • no difference in alignment efficiency or pain between conventional, superelastic and thermoelastic Niti wires	Riley & Bearn, 2008 Abdelrahman et al., 2015
Recommended reading	Evans & Durning, 1996; Kusy, 1997; Santoro et al., 2001a,b; Ireland & McDonald 2003; Riley & Bearn, 2008	

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Adhesives & Cements

Ideal properties	• strong enough to retain brackets for duration of treatment • not too strong that enamel damage on debond • good clinical handling • protect against caries • cheap • non-toxic • aesthetic • fluoride releasing	
Cements for bands	Glass poly(alkenoate) cements • many advantages over zinc oxyphosphate and zinc polycarboxylate • ↑ mean retentive strength • release fluoride and acts as a exogenous fluoride reservoir however no difference in decalcification rate compared to composite • cement bonds to enamel and metal, weakest link is band/ cement interface, sandblasting bands ↑ retention • easy to handle and remove, ↑ working time, wet bonding • light-cured glass ionomer cements, faster setting, ↑ initial and sustained bond strength • ↓ decalcification Types 1. <i>Conventional glass ionomer</i> - acid/base cement reaction 2. <i>Resin modified GIC - Dual cure</i> - hybrid of resin and glass ionomer with acid/base cement setting/light activation (approx 15% resin - HEMA) 3. <i>Resin modified GIC - Tri cure</i> - hybrid of resin and glass ionomer, chemical/light cure of resin/acid/base cement reaction (approx 15% resin) 4. <i>Compomer</i> - chemical or light cure of the resin; acid-base reaction of GIC component takes place with water from environment • systematic review demonstrated insufficient evidence to recommend 1 adhesive over any other for bonding molars	Millett et al., 1999 Millett et al., 1995 Foley et al., 2002 Millett et al., 2009
Bonding adhesives	Much development since original BisGMA systems were described Acrylics • use only with plastic brackets as bond strength is low • rarely used Composite (filled diacrylics) • resin (BisGMA) coupling agent • filler (glass particles) • curing: 1. chemical - paste/paste - paste/primer (no mix) 2. light activation - visible light (440-480nm) - activates free radicals 3. dual cure - chemical and light activation • dual cure is less technique sensitive, if fail to light cure long enough will chemically cure • most systems produce good bond strengths, individual preference will override manufacturers specifications • can get colour changing resin based adhesives, e.g. 3M Transbond colour changing with light curing; Grengloo (Ormco) colour change with light curing; Blugloo (Ormco) colour changing with temperature • no evidence supporting use of particular adhesive type	Mandall et al., 2018

Pre-coated brackets	• consistent adhesive presentation • less composite flash • command set - ideal for training • better cross-infection control • available with colour changing technology - pink prior to curing for ease of flash removal (same 3M Transbond colour changing adhesive also available separately) • no difference in failure rate between pre-coated and uncoated brackets	Bearn et al., 1995 Kula et al., 2002
Antibacterial adhesives	• incorporation of metacryloyloxydodecylpyridium bromide in attempt to ↓ demineralisation • does not appear to compromise bond strengths • fluoride releasing orthodontic resin adhesives also show promise for prevention of demineralisation • incorporation of other antimicrobial compounds such as TiO₂ and Zinc into bonding resins	Bulut et al., 2007 Buren et al., 2008 Poosti et al., 2012
Tooth preparation		Hu et al., 2013
Composite	Acid Etch • pumice - not needed • 37% o-phosphoric acid used • 15-60 seconds etch time • surface appearance the same with each time, more enamel loss the longer the etch time • bond strength is similar at 15, 30 and 60 seconds • debond rate similar for etch time of 15 or 60 seconds • 14µm average depth of resin tag	Barry, 1995 Bin Abdullah & Rock, 1996 Barry, 1995
	Resin Primer (sealants) • unfilled resin (methyl methacrylate monomer) • thought to ensure complete penetration of exposed enamel pores and increase bond strength/reliability • associated with dermatoses of dental professionals • potential source of Bisphenol-A - possible health risks related to oestrogenic action • omission of primer does not ↑ clinical bond failure rate • omission of primer does not ↓ in vitro bond strength ALTERNATIVELY Self-etching primers - etchant and primer combined in one solution Proposed advantages • ↓ number of steps in bond-up - therefore saves time • time saved overall during bond up (23 seconds/bracket) • ↓ enamel loss during etching than with convectional process • does not require rinsing therefore ↑ pt comfort • ↓ risk of etched enamel being left exposed as etching and priming occur simultaneously therefore theoretically ↓ risk of decalcification (no evidence) • less technique sensitive than conventional etching (can tolerate some moisture contamination) • clinical performance as good, if not better than conventional etching Disadvantages • bond strength lower than conventional etching and priming and differ between SEPs, but clinical performance as good • requires pumice prophylaxis prior to use (which can be omitted in conventional technique)	Pulgar et al., 2000 Wang & Tang, 1991; Tang et al., 2000a,b White, 2001; Fleming et al., 2012 Fleming et al., 2012 Hosein et al., 2004 Cacciafesta et al., 2003; Sfondrini et al., 2004 Asgari et al., 2002; Aljubouri et al., 2004 Korbmacher et al., 2002; Aljubouri et al., 2004 Ireland et al., 2003; Burgess et al., 2006

	• ↓ technique sensitivity is questionable, especially as no classic etched appearance makes it difficult to judge, and length of air-drying phase is important • calculations of time saved dubious as pumicing and priming stages not taken into account, SEPs need agitating on tooth surface between 3-20 seconds! • clinical performance may not be as good as conventional technique and varies between products • failure rates of SEP/conventional adhesives not significantly different • report of microleakage under metal and ceramic brackets bonded with SEPs	Dorminey et al., 2003 House et al., 2006; Burgess et al., 2006 Reis et al., 2008 Uysal et al., 2008
Resin modified glass poly (alkenoate) cement (RMGIC) Tooth preparation and bonding	• no consensus on enamel preparation prior to bonding except surface must be kept moist • 37% o-phosphoric acid may be used but not essential • 10% poly (acrylic acid) conditioner may be used but not essential • clean but not dry, keep surface moist for bands or bonds • no need to pumice • no etch and no drying, low failure rate • chemical covalent bond to enamel • may have a cariostatic effect by inhibition of plaque bacteria, but other influences may be more important in ↓ decalcification, e.g. diet and other fluoride sources • systematic review demonstrated weak evidence that GICs better than resin adhesive at preventing WSLs • light cured resin modified glass ionomer with etching (37% o-phosphoric acid) favourable option • bond strength ↑ more than 20 fold after 24hrs but ↓ enamel damage at debonding • lab measure bond strength lower but RMGIC have sufficient bond strength for orthodontic bonding - no worse failure rates over 1yr than composites • long working time • absorbs exogenous fluoride, e.g. from saliva and releases it, ↓ decalcification • no etching therefore ↓ enamel damage • covalent bond useful where etch pattern difficult, e.g. fluorosis or amelogenesis imperfecta • useful when dry field difficult, bonds in a wet environment • bond failure reported at enamel/resin interface	Ireland & Sherriff, 2002 Wright et al., 1996 Millett et al., 1999 Rogers et al., 2010 Millet & McCabe, 1996 Flores et al., 1999 Silverman et al., 1995; Choo et al., 2001; Hegarty et al., 2002 Hegarty et al., 2002
Fluorosis	• band instead of bond • RMGIC (no etch pattern needed) • longer etch time and long wash • thin mix • microabrasion ↑ retention to fluorosed teeth however unnecessary if adhesion promoter used, e.g. Scotchbond	Noble et al., 2008 Prado et al., 2020
Bonding to porcelain, amalgam, veneers and gold	Surface preparations • for porcelain use silane coupling agent: - hydrolysed 3M Scotch Prime - non-hydrolysed porcelain primer • for gold/amalgam - intermediate resin metal primers Mechanical preparation • diamond bur to roughen • sandblasting/microetching with aluminium oxide particles Chemical preparation for porcelain • use 9.3% hydrofluoric acid to etch to porcelain, produces similar or higher bonding strength as etched enamel • acidulated fluorophosphates (AFP)	Zachrisson et al., 1995; Zachrisson & Buyukyilmaz, 1993 Gillis & Redlich, 1998

Recommended reading	Ewoldsen & Demke, 2001; Mandall et al., 2002; Hu et al., 2013; Mandall et al., 2018; Prado et al., 2020	
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Types	Power chain/Power thread • cheap • rapid decay • clinicians use a wide range of forces • effective but needs changing every 4 weeks • varies significantly between different manufacturers • no chain → force ↑ 180g for more than 3 weeks if starting force ↓ 400g • 50-70% force decay by 21 days NiTi coil spring • expensive • low and constant force • do not require changing during space closure • RCT comparing space closure with power chain/NiTi coil springs/active ligatures found NiTi coils produced ↑ space closure/unit time than the other methods • no difference in canine retraction rate, tipping, rotation or root resorption between NiTi coil springs and power chain • clinically effective • not self-limiting • tend to fracture between eyelet and spring • when the wire diameter is ↑ and the lumen ↓, the load value becomes larger in both open and closed springs • when the pitch of coils is changed from fine to coarse the range of superelasticity ↑ • open coil spring shows more constant load value of superelasticity than closed: - closed coil spring: when coils are stretched lumen size → smaller and inclination of load deflection → acute - open coil spring: when coils are stretched lumen size → larger and inclination of curve → obtuse • force degradation 8-17% with initial force of 150-160g • loads exerted by NiTi-based coil springs varied from 99.8g (50% strain) to 245.1g (150% strain) • oral environment and thermocycling have only minor influence on their mechanical properties Elastomeric Modules • cheap • applies very heavy initial forces • first-day load losses can result in a 50-75% ↓ of initial force applied to malpositioned tooth • ↑ force loss occurred in first 24hrs • elastic modules exerted 216-459g of force initially; after 21 days of simulated tooth movement, significant ↓ in force exerted to 70-230g • force loss varies with different manufacturers of elastomeric modules • masticatory effects, tooth brushing, foods, salivary enzymes and oral temperature changes may affect force degradation	Lu et al., 1993 Chung et al., 1989 Dixon et al., 2002 Lu et al., 1993 Samuels et al., 1998 Dixon et al., 2002 Barsoum et al., 2021 Miura et al., 1988 Angolkar et al., 1992 Vidoni et al., 2010 Wichelhaus et al., 2010 Brantley et al., 1979 Taloumis et al., 1997 De Genova et al., 1985 Baty, 1994 Ash & Nikolai, 1978; Nattrass et al., 1997
Magnets	• rarely used • continuous force although force ↓ as distance between magnets ↑ (inverse square law) • types: aluminium-nickel-cobalt; samarium-cobalt; neodymium-iron-boron	Shastri et al., 2014

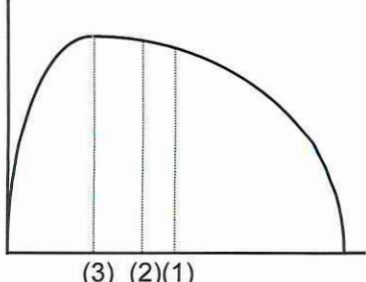
Research Aspects

Statistics

Research Methodology

Clinical Governance

Statistics

Data	2 main types: categorical (qualitative) data numerical (quantitative) data	
Categorical data	Nominal - categories with no particular order, e.g. gender or colour Ordinal - categories with some order, e.g. IOTN uses: - no treatment need - little treatment need - moderate treatment need - great treatment need - very great treatment need Ranks or scores - sets of categorical data placed in some numerical order, but this is NOT the same as numerical data, e.g. Goslon Yardstick ranks dental arch relationship from 1-5, note that a Goslon 'score' of 2 is not twice as good as a Goslon 'score' of 4, they are just categories	
Numerical data	Discrete - discrete numerical data can only take a fixed number of values, e.g. whole numbers Continuous - continuous numerical data is quoted to a greater precision, e.g. using decimal places; in principle, any number across some range	
Why the type of data is important?	The type of data (categorical or numerical) is crucial in determining which analysis method is appropriate and valid Tests for numerical data might include: - t test for independent samples - paired t test - one way analysis of variance (ANOVA) - Wilcoxon's signed rank test - Kruskal-Wallis test Tests for categorical data might include: - Chi square test - Odds Ratio - Risk Ratio - Generalised linear models	
Normal distribution	- represented by family of curves, NOT single unique curve - curves are characteristically bell shaped and symmetrical, but vary in height - the exact distribution is determined by the mean and standard deviation	
Measurement of central tendency	Measured in 3 main ways (see diagram): - arithmetic mean (1) - average value in a population - median (2) - middle value in a population - mode (3) - most common value NB :- (1) (2) and (3) are not necessarily the same 	

Measurement of the variability (spread of data)	Range - the values at the top and bottom denote the findings furthest from the mean - however quoting the range fails to give an indication of the spread of observations about the mean Interquartile Range - values that capture the middle 50% of the distribution - upper and lower quartiles (75th-25th percentile) Standard deviation (SD) - this describes the spread of observations either side of the mean - SD should only be used when the population or data sample approximately falls into a normal distribution	
Summarising data	- measurement of central tendency - measurement of the spread of data (i.e. the variability)	
Why is SD so useful ?	it describes the distribution around the mean: 1SD = 68.2% of spread around the mean, 2SD = 95.4% and 3SD = 99.6%	
Standard error of the mean (SEM)	- if several samples are taken from a population, each sample will have its own mean - it is possible to calculate the standard deviation of the means of a large number of samples drawn from a population - this is known as the Standard Error of the Mean (SEM) - SEM provides an indication of the precision of the sample mean as an estimate of the population mean	
Confidence limits	- this is a way of stating the probability that the mean for a population will lie between a range of values, e.g. if a sample mean = 5 and the standard error of the mean is 2, a 95% confidence limit is calculated as: $5 \pm (1.96 \times 2) = -1.08 \text{ to } 8.92$ - a 95% confidence interval implies that there is a 95% chance that the true population mean lies within a given range of values	
Probability limits	1.96 (almost 2) SD above and below the mean marks the point within which 95% of the populations lie, e.g. for a normally distributed population with a mean of 5 and a SD of 3 the 95% probability limit is given by: $5 \pm (1.96 \times 3)$ giving a range of 0.88-10.88 95% of the observations should lie within this range - there is only a 5% probability that an observation will occur outside this range - this probability is commonly expressed as a fraction of 1 instead of 100 so that a 5% probability is written as $p=0.05$	
Simple tests of statistical significance	- there are a number of statistical tests used to determine if 2 samples come from the same population or whether they are likely to have come from different populations - these are called hypothesis tests or more commonly significance tests	
Null hypothesis	- when 2 samples are compared, the hypothesis that the 2 samples come from the same population is investigated - by convention the hypothesis that there is <i>no difference between the populations</i> is tested, i.e. if there is no difference between the populations then the hypothesis is not rejected - this is known as the null hypothesis	

t test for independent sample means	- used for comparing two independent sample means - assumes that the variance obtained from each sample is an estimate of the true population variance and is the same for the two populations - assumes that the samples are taken from a normally distributed population	
Paired t test	- assumes that the samples are taken from a normally distributed population - used for comparing two paired samples with each other, rather than two independent samples, e.g. when comparing two alternative treatment therapies, paired observations are made by either: 1) testing the same individual on two occasions or more commonly: 2) testing a matching pair of individuals Matching pairs of subjects - useful in allowing treatment effects to be compared whilst minimising the influence of any disturbing variables - limited by the ability to achieve perfectly matched pairs of subjects	
Analysis of variance (ANOVA)	- used for comparing three or more independent sample means (<i>t</i> test is used when comparing two independent sample means) - essentially a significance test which compares the 'within group' variance and the 'between group' variance - if the variances are similar, varying only by chance, the null hypothesis is not rejected - if there is a genuine difference between one or more of the sample means the 'between group' estimate of the variance will be large indicating a real difference between the population means	
Chi squared test (χ^2)	- does not provide a full analysis and description of data - will determine if the distribution of categorical observations is in accordance with those that might be expected from a specified theory or hypothesis - only carried out on actual numbers of occurrences - not percentages - the number of observed frequencies is compared with the expected frequency (from the hypothesis) by plotting contingency tables	
Logarithmic transformation	Parametric statistical tests are suitable when the data has a normal distribution, in practice, the distribution of quantitative measurements may be skewed (or shifted to one side) and does not follow a normal distribution Logarithmic transformation used to make the data distribution approximate more closely to a normal distribution - this allows parametrical statistical tests to be used	
Non-parametric hypothesis tests	Not all data follows a normal distribution in spite of attempts to transform it logarithmically, in such cases data can be analysed using non-parametric statistics Non-parametric tests: - less powerful than parametric tests - tend to be more limited (than parametric tests) in terms of predictions that can be made from them, e.g. they cannot describe the variance in observations in terms of SD - mainly rank the data observations in terms of magnitude and then test these rankings rather than testing the actual data observations - useful for analysing ranked data	

Common non-parametric tests	Wilcoxon's sign rank test • non-parametric equivalent of the t test for paired data Wilcoxon's two sample rank test • non-parametric equivalent of the t test for unpaired data • determines if 2 unmatched samples are derived from the same population or whether a difference is likely to exist Mann-Whitney U test • popular test for unpaired data that gives equivalent results to the Wilcoxon's two sample test	
Correlation (r)	• way of quantifying the degree of association between two or more variables • r denotes the coefficient of correlation • for straight line (linear) correlations r is measured on a scale of +1 through 0 to -1 • if $r = +1$ there is perfect positive correlation between the variables so that as one variable $\uparrow$ so does the other • if $r = 0$ there is no correlation between the variables or a correlation may exist but it is non linear • if $r = -1$ there is perfect negative correlation between the variables so that as one variable $\uparrow$ the other one $\downarrow$ • in practice, plotting a scatter diagram of the data points is strongly recommended in order to visualise the distribution of the data and any correlation between variables Pearson's correlation coefficient • the correlation coefficient used for parametric data (when there is a Normal distribution of variable y for a given variable x) Spearman's correlation coefficient • the non-parametric equivalent of Pearson's correlation coefficient	
Regression	• means of defining the association between two or more variables in terms of an algebraic equation • allows predictions to be made of how one variable changes on average with another, i.e. the value of one variable can be determined if the value of the second variable is known Linear regression • the most simple type of regression • association between two variables is described in terms of a straight line equation, i.e. $y = a + b \cdot x$ Logarithmic regression • there are several other types of regression equations involving logarithmic transformation of the x or y values	
Interclass correlation (ICC)	• assesses rating reliability by comparing the variability of different ratings of the same subject to the total variation across all ratings and subjects • allows assessment of either the reliability of individual raters or of the reliability of the mean rating score • is related to kappa • different classes of ICC can be used depending on the agreement being investigated, these are known as cases • ICC is beginning to replace kappa	Weir, 2005
Kappa statistic (κ)	• used to measure level of agreement • kappa (κ) is measured from -1 through 0 to +1 so that: - If $\kappa = +1$, this represents perfect agreement - If $\kappa = 0$, agreement is no better than chance - If $\kappa = -1$, worse than chance agreement	

	- useful statistic for measuring the diagnostic consistency between examiners Inter-examiner agreement: the agreement between two separate examiners Intra-examiner agreement: the agreement between a single examiner on two occasions Interpretation of kappa - interpretation of κ values between 0 and 1 is arbitrary, however Altman recommends:<table><tr><th>Value of κ</th><th>Strength of agreement</th></tr><tr><td>< 0.20</td><td>Poor</td></tr><tr><td>0.21-0.40</td><td>Fair</td></tr><tr><td>0.41-0.60</td><td>Moderate</td></tr><tr><td>0.61-0.81</td><td>Good</td></tr><tr><td>0.81-1.0</td><td>Very good</td></tr></table> - with frequency distributions that differ greatly, kappa values cannot be directly compared	Value of κ	Strength of agreement	< 0.20	Poor	0.21-0.40	Fair	0.41-0.60	Moderate	0.61-0.81	Good	0.81-1.0	Very good	Altman, 1991 Roberts & Richmond, 1997
Value of κ	Strength of agreement													
< 0.20	Poor													
0.21-0.40	Fair													
0.41-0.60	Moderate													
0.61-0.81	Good													
0.81-1.0	Very good													
Weighted kappa	- this statistic is similar to kappa but takes into account the 'near misses' in agreement - should give higher values for agreement than an unweighted kappa - choice of weight should be made clear in research report	Roberts & Richmond, 1997												
Recommended reading	Altman, 1991; Altman et al., 2000													

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Study design protocol	Planning • select aims (usually broad) • state objectives, these should be capable of statistical description and analysis (more specific and focussed than aims) • null hypothesis (always assumes there is no difference) • ethical issues, e.g. welfare of subjects (pts), should time and money be spent researching this subject, pt consent • PICO process can be used to frame and answer a clinical question (P - pt/problem/population; I - intervention; C - comparison/control; O - outcomes) Design • define the study population • define the measuring techniques and instruments • power calculations to determine required sample sizes (also add 10% to allow for dropouts) • calibration of examiners • pilot study • consider having control groups • try to eliminate sources of bias (single operator/examiner, blinding during data collection and analysis) • Consolidated Standards of Reporting Trials (CONSORT) guidelines developed to assess reporting of randomized clinical trials in journals, ensures studies have been carried out satisfactorily • many journals require researchers to submit their manuscripts with completed checklist outlined by the CONSORT guidelines • COMET (Core Outcome Measures in Effectiveness Trials) initiative encourages the development and application of agreed standardised sets of core outcomes which represent minimum that should be measured and reported in all clinical trials, audits of practice or other forms of research for a specific condition Data collection Data processing and analysis - type of analysis should be predetermined before starting the research Interpretation of data analysis - do not just rely on statistical significance, also consider clinical significance Conclusions Publication?	Atwal & Benson, 2019a,b Davies, 2011 Newcombe, 2000 www.comet-initiative.org
Classification of studies	Descriptive (Observational) studies • researcher records data and does not influence results • can be prospective or retrospective, e.g. epidemiological studies, audit studies • analytical studies are a type of descriptive study that investigates association only - not causality Experimental studies • researcher deliberately influences events and investigates the effects of this intervention • experimental studies look for true causality - more advanced than analytical studies • tend to be prospective, e.g. laboratory studies, clinical trials, field or community trials Method studies • establishes some method in a clinical process • investigates the validity of a particular measurement	

	Cross-sectional studies • individuals are studied only once • prevalence of a disease at one moment in time Longitudinal studies • individuals are studied on more than one occasion • investigates the changes over time • incidence of a disease - number of new cases over a given time • most experimental studies are longitudinal • observational studies can be longitudinal (e.g. cohort studies) or cross-sectional (e.g. case control studies) “Traditional” review • reviews are a form of secondary research • findings of a number of studies are summarised • reviews may be subjective and their conclusions biased if all relevant studies fail to be included Systematic review • systematic evaluation of all relevant papers on a subject • papers are reviewed according to a strict protocol to help ↓ bias and selectivity • PRISMA - Preferred Reporting Items for Systematic Reviews and Meta-Analyses • even with systematic reviews the problem of trials that report a positive effect are over reported and trials reporting an insignificant effect are under reported Meta analysis • mathematical synthesis of the results of two or more primary studies that addressed the same hypothesis in the same way • quantitative synthesis of studies → overall summary • produces graphical output → forest plots, with summary diamonds positioned with respect to the line of no effect • methods used for review need to be valid and reliable • pooling data in this way ↓ random error even further • generalisation of the findings is ↑ • bias may be introduced if all relevant studies are not included - use funnel plots or contour funnel plots to assess publication and other bias The Cochrane Collaboration • launched in 1995 • provides a database of controlled trials and systemic reviews • provides guidelines on preparation of good clinic trials and systemic reviews	Moher et al., 2009 Song et al., 1997 Papageorgiou, 2014 www.cochrane.org Greenhalgh, 1997 Peters et al., 2007 www.cochrane.org
Hierarchy of clinical research methods	Anecdotal case report • many new developments are first described in case reports • tend to lack number of subjects and findings need further substantiation Case series • shows whether technique can consistently achieve favourable results • lacks objectivity - unable to compare one technique with another Retrospective comparative studies, e.g. inter-centre comparisons • direct comparison is made between two or more treatments (with or without a control group) • selective bias may be introduced in retrospective studies	Roberts et al., 1991; Sandy & Roberts-Harry, 1993 Harrison et al., 1996

	• difficult to match groups in all respects except for the treatment effect under study Advantages: • provides large numbers of subjects in which to compare treatment methods • prospectively planned recall of subjects - allows data to be collected in a standardised way in order to compare treatment methods Disadvantages: • lack sensitivity to detect key beneficial or harmful features of a particular treatment • can only make broad comparisons between treatment Randomised prospective control trials • ultimate in scientific validity • randomisation avoids any bias in treatment allocation and unknown confounders likely to be equally distributed • more sensitive in detecting key beneficial effect • ethical dilemma - should a better (but not proven) treatment be withheld in place of alternative treatment • <i>Hawthorne effect</i> - change in behaviour of clinician and pts as they know they are participating in a trial Meta-analysis • use more than one randomised control trial	
Pt Questionnaires	• questionnaires are instruments for gathering data to answer a specific question • can be used in research, quality improvement and to gather clinical information • common uses include: epidemiology; outcome of an intervention; experience of a process	Barber & Shelton, 2021
Validity	• the extent to which (in the absence of measurement error) the value obtained represents the object of interest, i.e. <i>are you measuring what you think you are?</i> Face validity (logical validity) • does it actually make sense? e.g. using A point is not a logical choice for maxillary Sk base Content validity • does the measure include all relevant variables in order to assess something? Consensus validity • agreement among a lot of people Criterion validity (concurrent validity) • assessment of a measure against a true golden standard Construct validity • use of other variables to assess the validity of another measurement, e.g. sick leave used to validate what employees felt about their environment N.B. - face and criterion validity are the most important	
Reproducibility	• the closeness of successive measurements • errors in measurement can be both systematic or random	
Reliability	• can represent reproducibility • often used in a broader sense to encompass both reproducibility and validity	
Measurement error	• can be systematic or random • observed value = true value + systematic error + random error	
Systematic error	• a tendency to over or underestimate a parameter giving a biased or unrepresentative sample (remember: you have to assume that the sample is representative of a wider population)	

	• a bias is a systematic error which can affect interpretation • bias can occur through structural or methodological deficiencies in a study, e.g. non-randomisation • bias can be introduced by subconsciously weighting results when 2 series of measurements are compared • random sampling and double blind experimental designs are important in ↓ bias Detection bias • do we get better records on successful cases? Exclusion bias • were all the cases included in the results? • poor response • non-compliance Proficiency bias • appliance A is 10% better than B • clinician 1 is 5% better than 2 - if 2 uses A the result will be better than 1 using B Reporting bias • insignificant or negative findings are rarely reported • significant findings tend to be reported and published	Atwal & Benson, 2019a,b
Random error	• this is the variability due to chance • important because it adds to the natural variability of observations and may obscure real differences between groups • ↑ the number of observations, e.g. repeating measurements and taking an average value is an important way of reducing random error • an ↑ in random error may be noted with ↑ in true value • <i>attenuation</i> is the ↓ in correlation observed between variables due to random error	Roberts & Richmond, 1997
Error estimation	• estimation of reproducibility error is an important part of experimental study • error estimation normally involves the replication of a certain number of observations • replicated measurements should be chosen at random and after a suitable time interval following the initial measurements • important to distinguish between systematic and random error Error estimation for numerical data Several methods are used: 1) Paired <i>t</i> test • determines if there are any significant differences between observations, however supposing 'no significant difference' is found, it is impossible to determine if this is due to ↑ variability or because there is no systematic error - this method is therefore not ideal 2) Calculating a correlation coefficient (<i>r</i>) • this method should be avoided • only measures the association (or correlation) between repeated measurements • it fails to measure the systematic difference between readings, i.e. the repeated observations may correlate closely with each other, but an enormous systematic difference may exist between them 3) Dahlberg's method • Dahlberg proposed a formula to determine the total error variance, however total error variance will only equate with random error if there is zero systematic error or bias	Dahlberg, 1940

	- this underlines the problem with Dahlberg - its inability to distinguish between systematic and random error particularly with small samples - in spite of this problem, Dahlberg's method is widely used 4) Quoting the mean difference and the standard deviation of the difference - the mean difference between the repeated measurements gives a measure of the systematic error - SD of the difference gives a measure of the random error - quoting these two values allows differentiation between random and systematic error Error estimation for categorical data - Kappa (κ) statistic is used to measure the agreement between the 2 sets of observations	Springate, 2012
Interpretation of error variance	- interpretation of error variance is arbitrary and should depend on what you are studying - popular convention is that the error variance should not be greater than 10% of the total variance - systematic error should be looked upon as being more serious than random error - frequently it will be easier to include more measurements rather than going to extreme lengths to ↓ the error variance with the same number of measurements	Houston, 1983
Evaluation of papers	Title - is the research question chosen worth answering? Abstract - oversimplification? - omission? - misrepresentation? Introduction - is introduction relevant to the problem being studied? - are aims and objectives clearly stated? Methodology - the most important section - is their method of measurement valid? - method error - have errors in the method and reproducibility been taken into consideration? - double blind technique to eliminate bias? Subjects - ideally sample chosen randomly represents population - adequate number? - are subjects matched for all relevant variables except the one being tested? - is the control group adequate or poorly matched? - are the numbers sufficient - was a sample size (power) calculation performed Results - is any data missing? - is the data presented clearly? - have inappropriate statistical tests been used? e.g. do they treat categorical data or rankings as if it is numerical data - have confidence intervals or significance levels been quoted? (many journals now favour confidence intervals) Discussion - have they measured what they set out to investigate? - are there any unfulfilled aims? - are results discussed in context of the current literature? - are conclusions that are drawn valid from the findings?	

	• are the findings generalisable? • have the limitations of the study been adequately described? • will it change your practise?	
Recommended reading	Greenhalgh, 1997; Atwal & Benson, 2019a,b; Barber & Shelton, 2021	

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Definition	<i>Clinical governance</i> describes the structures, processes and culture needed to ensure that healthcare organisations - and all individuals within them - can assure the quality of the care they provide and are continuously seeking to improve it	Dept of Health, 2011
Clinical Governance framework	7 areas of activity (previously known as the 7 pillars) 1) Clinical effectiveness and audit 2) Research 3) Risk management 4) Education and training 5) Pt and public involvement 6) Information management including data protection 7) Staff and staff management 	
Development	- background to <i>Clinical Governance</i> comes from the document <i>A First Class Service</i> which outlines ways to attain high standards of care - domains for improvement; <i>setting standards, delivering standards, monitoring standards</i> - governance of clinicians by clinicians - support for the clinicians from managers - involvement of clinicians in management	Dept of Health, 1998
Setting standards	Focus is the <i>National Institute for Clinical Excellence (NICE)</i>, with remit for appraisal and guidance - acts to unify on-going audits and confidential inquiries - disseminates clinical information	
Monitoring standards	- Care Quality Commission (Health and Social Care Act 2008 (Regulated Activities) Regulations 2010, and the Care Quality Commission (Registration) Regulations 2009) is involved in monitoring standards, responsible for ensuring clinical governance is implemented 28 outcomes contributing to clinical governance - self regulation involves ethical behavior and professionalism of the orthodontic team, NHS Trusts and the GDC/GMC including lay person involvement	www.cqc.org.uk
Delivering standards	- involves concepts of lifelong learning and continuing dental education - this should lead to implementation of better practice and periodic review	
Clinical Effectiveness	concerned with <i>measuring, monitoring and improving clinical care</i> to create an environment where clinical excellence will flourish	Dept of Health, 1998

Clinical Audit	- on-going cycle (or spiral) of setting standards, observing current practice and making necessary changes - can be used to look at structure, process and outcome - assesses the extent to which clinical practice meets targets identified by a standard - developmental audit - practitioners look at their own practice to learn and improve from the audit procedure - judgmental audit - use of audit by others to determine the ability or efficacy of a particular practitioner or unit, within the defined criteria - audit may also be used as part of a service evaluation to see what standard is being achieved - audit can be used to set explicit criteria which: - allows setting of guidelines to achieve standards - allows consistency of practice between pts - allows re-audit to see if criteria previously set are being met and to set date for further re-audit	
Audit versus research	Research - designed to establish best practice - usually involves testing a hypothesis and is designed to be replicated and ideally generalizable to other groups - systematic investigation to increase knowledge - tests a hypothesis - may involve experiments on subjects/people - may inconvenience pt outwith normal clinical management - may involve new treatment Audit - is to evaluate how real practice matches a standard and is specific to this group only - systematic review of care against criteria - measured against a standard - never experiments on people/subjects - never disturbs pts beyond that required for clinical management - never involves a new treatment	
Measuring systems and data	- prospective audit is the most valuable - need appropriate sample size and to avoid bias - all measurements need standardisation - need valid data which is ideally obtained from a standardised source, e.g. questionnaire proforma - appropriate statistical handling of data	
Post audit	- identification of areas of strength and weakness - disseminate findings to appropriate parties/stakeholders - change in working practice may be instituted - re-audit once implemented change to review practice against a standard	
Clinical Incident	- defined as any unplanned event which causes, or has the potential to cause, harm to a pt - a patient safety incident is any unintended or unexpected incident which could have or did lead to harm for one or more pts receiving NHS care	
Recommended reading	Healthcare Quality and Improvement Partnership Local Clinical Audit Handbook for Clinicians available to download from www.hqip.org.uk	

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Miscellaneous

Temporo-Mandibular Dysfunction (TMD)

Obstructive Sleep Apnoea (OSA)

Relevant Medical Disorders

Role of Dental Care Professional (DCP)

Radiation Safety

Temporo-Mandibular Dysfunction (TMD)

Definition	Group of related disorders with common signs and symptoms affecting the joint, facial muscles or both • rarely encountered in children and young adolescents and most seen in adults Signs and symptoms that are present: • limited mandibular opening (<40mm males;<35 mm females) • ↓ lateral mandibular excursions of <1 incisor width • joint noise and pain • tender muscles of mastication • popping or tinnitus of the ears • headaches	Luther, 1998 Riolo et al., 1987 Harris et al., 1993 Solberg et al., 1986
Aetiology	• multifactorial - inflammatory - psychological - degenerative - dysfunctional - idiopathic	Mohlin & Thilander, 1984
Types	• TMD due to internal joint pathology (including displacement or destruction of the intra-articular disk) • TMD due to muscle spasm and fatigue, related to excessive clenching and grinding in response to stress	Proffit, 2007
Incidence	Variable incidences recorded: • 6-18yr olds - 12.2% (sample = 7337) • 6-16yr olds - 35% (sample = 304) • 7-84% depending on signs and symptoms recorded • prevalence and severity of TMD ↓ from 19-30yrs old, where 25% showed a complete recovery • F:M = 1.5-2:1	Motegi et al., 1992 Williamson, 1977 Mohlin et al., 2004 Sharma & Ohrbach, 2018
Indices	Helkimo Index • sums up TMD symptoms and assigns a grade of severity when a certain level is exceeded • insufficient evidence to support or to document the validity of this index • index contains useful elements and should be adapted rather than replaced to improve its' validity Craniomandibular Index • addresses the problems of validity and reproducibility associated with Helkimo Index • more cumbersome and is therefore rarely used	Helkimo, 1974, 1976 Van der Weele & Dibbets, 1987 Friction & Schiffman, 1986, 1987
Does malocclusion cause TMD?	Evidence for contention: • weak evidence: - AOB, excess OJ (either CI II or III) - posterior crossbite, AOB, ↑ OJ - forced bite between RCP and ICP - deep OB Evidence against the contention: • large studies only show weak correlations • only 5-35% of the population have TMD yet 60% have a malocclusion • TMD is no more common in pts with severe malocclusions than controls with no malocclusions	Thilander et al., 2002 Riolo et al., 1987 Egermark et al., 2003 Carlsson et al., 2002 Paquette et al., 1992; Luppanapornlarp & Johnston, 1993
Do occlusal interferences cause TMD?	Evidence for the contention: • not a straight forward relationship	Huang et al., 2004

	- double blind study: signs and symptoms of TMD ↑ x2 in a group of subjects with artificially induced non-working side interferences compared with controls Evidence against the contention: - non-working side contacts are common (91% pts found to have non-working side contacts), therefore statistically difficult to find control groups - mandibular displacements from retruded contact position to intercuspal position are common with more than 90% of population having slide of >1mm; larger slides more often produce lateral deviation which is assoc with TMD - slide altered by ortho or equilibration will tend to return toward pre-existing condition - TMD symptoms ↑ in both control and experimental groups in the double blind 'induced non-working side contacts' study - pts with a 'Six Keys Occlusion' had the highest prevalence of non-working side contacts	Magnusson & Enbom, 1984 Sadowsky & BeGole, 1980 Ramfjord et al., 1983; Solow, 1980 Forsell et al., 1986 Rinchuse & Sassouni, 1983
Does orthodontic treatment cause TMD?	Evidence for the contention (historical): - Roth's work demonstrating that the symptoms of TMD from 9 post-treatment cases resolved once they were equilibrated using positioning splints - no control group used Evidence against the contention: 20yr follow up post-treatment: no difference in signs and symptoms	Roth, 1973 Egermark et al., 2003
Do Xtns cause TMD?	Evidence for the contention: Personal opinions: - functional orthodontists think that Xtns cause condyle to be displaced distally as incisors retracted into Xtn spaces Evidence against the contention: - samples of Xtn and non-Xtn cases show that the frequency of TMD symptoms is the same in both groups - no ↑ prevalence of TMD in subjects treated with orthodontic Xtns - no ↑ prevalence of TMD in pts where premolars Xtn and the use of CI II intermaxillary elastics - small improvement in TMD in Xtn and non-Xtn cases	Bowbeer, 1987 Paquette et al., 1992; Luppapornlarp & Johnston, 1993; Luecke & Johnston, 1992; Mohlin et al., 2004 McLaughlin & Bennett, 1995 Kremenak et al., 1992
Does orthodontics improve TMD?	Evidence for the contention: Personal opinion: - Proffit believed that orthodontic treatment → the periodontal ligament (PDL) to be temporarily painful which ↓ any bruxing habits and therefore rests the TMJs, in turn this ↓ TMD symptoms - TMD ↓ in pts having FAs - not statistically significant - TMD ↓ in pts having FAs - this was small but statistically significant Evidence against the contention: 20yr follow-up: orthodontic treatment in childhood does not ↑ the risk of developing TMD	Sadowsky & BeGole, 1980 Kremenak et al., 1992 Egermark et al., 2003, 2005
Orthognathic surgery and TMD	- orthognathic surgery does not necessarily ↑ or ↓ the signs/symptoms of TMD - a 5yr follow-up post surgery found that symptoms/signs ↓ in some pts and remained the same in others	Egermark et al., 2000

Do changes in disc position due to orthodontics cause TMD?	Evidence against the contention: 49% of 205 pts with a disc displacement diagnosed with arthrography did not have a TMJ click - this weakens argument that a click is a sign of TMD and questions the validity of using arthrography to diagnose TMD - no studies showing changes in disc position after orthodontic treatment using arthrography and MRI	Kircos et al., 1987 Roberts et al., 1986
Do changes in condylar position cause TMD?	Evidence for the contention: Personal opinions: 'functional orthodontists' believe there should be 3mm of joint space behind condyle; they believe that Xtns force the condyle distally and trap the disc anteriorly → TMD - Roth favours a 'rear most, mid-most and upper most' position for the condyle in order to avoid occlusal interferences Evidence against the contention: - orthodontic treatment does not force the condyle distally, in fact it moves temporarily forwards 0.7mm (in 70%), movement due to loss of anchorage in buccal segments - the condylar positions proposed by the functional orthodontists and Roth could not be verified - inducing a change in condylar position is not possible using repositioning splints 25% of asymptomatic individuals with CI I occlusion have posteriorly positioned condyles - data collected from 7008 individuals showed no link between malocclusion or functional occlusion and TMD	Bowbeer, 1987 Roth, 1981 Luecke & Johnston, 1992 Luecke & Johnston, 1992 Johnston, 1988 Pullinger et al., 1987 Gesch et al., 2004
In summary	- no evidence that orthodontic treatment causes or cures TMD - no evidence that occlusal adjustment prevents or treats TMD compared to controls	Sadowsky, 1992 Huang et al., 2004
Recommended reading	Luther, 2007a,b; BOS, 2012	

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Obstructive Sleep Apnoea / Hypopnoea Syndrome (OSAHS)

Definition	- OSAHA can be defined as the co-existence of excessive daytime sleepiness and irregular breathing at night - apnoea is a pause in breathing that lasts for at least 10 seconds - most common sleep related breathing disorder increasingly recognized as a serious public health issue and potentially life threatening - repeated collapse of upper airway during sleep causing cessation of breathing despite inspiratory effort - obstruction may be complete, with total obstruction of the airway (apnoea) or partial (hypopnoea) causing hypoventilation	SIGN, 2003 Battagel, 1996
Measurement	- severity measured using the apnoea/hypopnoea index (AHI): number of apnoea events/hrs of sleep - mild - AHI 5-14/hr - moderate - AHI 15-30/hr - severe - AHI >30/hr	
Risk factors	↑ prevalence of OSAHS in people with: • ↑ BMI • type 2 diabetes • cardiac arrhythmia/stroke/TIA/chronic heart failure • moderate/severe asthma • hypothyroidism • polycystic ovary syndrome	NICE guidelines, 2021
When to suspect OSAHS	Nocturnal symptoms • snoring (majority of snorers do not have OSAHS) • choking and restlessness • nocturia (waking from sleep to urinate) Diurnal symptoms • unexplained tiredness and fatigue • hypersomnolence (falling asleep at inappropriate times) • waking headaches • impaired memory and cognitive dysfunction • impaired quality of life Potential medical consequences of OSAHS • hypertension and cardiac problems • untreated OSAHS can be associated with a range of adverse cardiovascular health outcomes such as hypertension, stroke, congestive heart failure and atrial fibrillation	
Aetiology	Multifactorial - but associated factors include: Anatomical factors • generally shorter cranial base, max and mand, although range of Sk morphologies seen • ↓ oro-pharyngeal dimensions between soft palate, tongue and pharyngeal wall • tongue size normal, ↓ functional space due to short mand Pathophysiological factors • when lying down and asleep airway dimensions modified by posture and muscle tone • obesity leads to fatty deposits and narrowing of the oro-pharynx	Baik et al., 2002
Diagnosis	• history from pt and sleeping partner • overnight polysomnography in sleep laboratory or at home, measurements include traces of heart, brain and respiratory activity, oxygen saturation, oral and nasal airflow as well as sounds and body position	

	subjective assessment of daytime sleepiness using the Epworth Sleepiness Scale (ESS) or STOP-Bang questionnaire	
Management	- multidisciplinary care: involves respiratory/thoracic physicians, ENT, maxillo-facial surgeons, orthodontists and dentists Management options involve: Behavioural modification including: - weight loss programmes - obesity ↑ the prevalence and severity of OSAHS - stop smoking initiatives - smoking causes upper airway inflammation - alcohol avoidance - excess alcohol ↓ upper airway muscular tone - advice on sleep hygiene - alteration of sleeping position - positional modifiers - elimination of aggravating factors - control of chronic obstructive airway disease, asthma, hypothyroidism Non-surgical options: - continuous positive airway pressure (CPAP) delivers continuous air under pressure via tight fitting nasal/facial mask (considered gold standard treatment), disadvantages - noisy, cumbersome and efficacy highly reliant on pt compliance - mandibular advancement appliances (MAA) offered as alternative to pts who cannot tolerate CPAP - although CPAP shows improved efficacy compared with MAA, MAA demonstrates improved long-term compliance compared with CPAP therefore overall effectiveness thought to be similar Surgical options: - mandibular or bimaxillary advancement surgery - surgery to reposition hyoid - surgical correction of nasal and naso-pharyngeal obstructions (septal deviation, polyps etc) - pharyngeal surgery (uvulopalatopharyngoplasty (UPPP), laser associated uvulopalatopharyngoplasty (LAUP)) not recommended for OSA - tracheotomy - if all other options have been exhausted	Sullivan et al., 1981 SIGN, 2003 Schwartz et al., 2018 NICE Guidelines, 2021 SIGN, 2003
Mandibular advancement appliances (MAA)	- primary action - to ↑ and stabilize the oropharyngeal and/or hypopharyngeal airway space - many designs described, include vacuum formed devices, CoCr, cribbed activator, removable Herbst with intermaxillary elastics; 1 piece or titratable - resemble functional appliance with protrusive bite (75% maximum protrusion suggested) and as little vertical opening as possible - worn for minimum of 4-6hrs/night for appreciable benefit - short-term side effects: hypersalivation, muscle discomfort, dry mouth - longer term effects: similar to functional appliances - retroclination of ULS and proclination of LLS → alteration of ant occlusion - when comparing efficiency and efficacy of MAA - 1° outcome measures = HRQoL, AHI, ESS - quality of evidence is often low due to ↑ risk of bias - blinding of participants/investigators not possible, subjective nature of outcomes, mixed severity of trial population, short trial periods	Lim et al., 2006 Rose et al., 2002; Johal & Battagel, 2001 Ellis et al., 2003 Johal & Desai, 2018 NICE Guidelines, 2021 NICE Guidelines, 2021

	• custom made MAA has improved clinical effectiveness especially in terms of retention, pt comfort and compliance compared with non-customised MAA • follow up (F2F or virtual) at 3mth to review MAA and symptom improvement and then subsequent review according to pt needs and optimal symptomatic control • indemnity providers request that clinicians prescribing MAA should have completed documented training, liaise with pt, GMP/Sleep Physicians and consent pt regarding short and long-term side effects	Johal et al., 2017
Recommended reading	NICE Guidelines, 2021	

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Relevant Medical Disorders

Relevance	- pts seeking orthodontics may have complicated medical histories and drug regimens, some of which may have clinical implications - need to take a careful medical history to assess the risks of treatment for that particular pt - medical history should be updated regularly - orthodontists see their pts every 6-8 weeks so must remain vigilant for changes in general health - may need to work with other health care professionals to create ideal treatment plan - orthodontic staff need to update their medical emergencies training regularly	BOS, 2016a BOS, 2016b Alawsi et al., 2020
Cardiovascular Disease		
Infective endocarditis (IE) (also known as bacterial endocarditis)	- rare and serious complication of dental treatment - prerequisite for development IE is bacteraemia 4 case reports of BE diagnosed during or immediately after orthodontic treatment - none associated with banding, debanding or adjustments of appliances - removal of orthodontic mini-implants not shown to have any associated bacteraemia - placement of separators was shown to be associated with bacteraemia 30 seconds after the procedure - maintaining an exemplary level of oral hygiene and minimising the use of separators would be advisable - NICE guideline (CR64) recommend that pts undergoing dental procedures: - should not routinely be offered antibiotic prophylaxis - should not be offered a chlorhexidine mouthwash against IE - orthodontic treatment not contraindicated but a non-Xtn approach may be preferred if possible - if Xtn planned, inform pt's cardiologist - symptoms of IE: malaise, pyrexia, weight loss, pallor, digit clubbing, splinter haemorrhages, rashes - Osler's nodes, heart murmur, heart failure	Hobson & Clark, 1995 Dajani et al., 1997; Burden et al., 2004 Livas et al., 2014 Lucas et al., 2002 Alawsi et al., 2020 NICE, 2016 Alawsi et al., 2020
Haematological Disease		
Pts with bleeding problems	- Haemophilia A (Deficiency Factor VIII), Haemophilia B (Deficiency Factor IX), von Willebrand's disease - treatment not contra-indicated, consult haematologist for advice prior to any invasive treatment - if Xtn cannot be avoided, primary closure with suturing and supplementation of Factor VIII may be required - avoid SS ties, self ligation preferred to conventional brackets - care inserting and removing archwires - keep treatment time short	Alawsi et al., 2020 Alawsi et al., 2020
Sickle cell anaemia	- chronic disease due to genetic disorder with haemoglobin gene mutation; deoxygenation, e.g. during GA induces red cells to deform to a sickle shape - recommended to ↓ orthodontic forces and ↑ resting periods between activation to restore the regional microcirculation - consider carefully procedures that require GA	Alves et al., 2006
Haematological malignancies	50% of childhood malignancies are leukaemias or lymphomas (most common: acute lymphoblastic) - main problems are gingival bleeding and ulceration	Sheller & Williams, 1996

	- management includes chemotherapy, radiotherapy and bone marrow transplant 60% are long term survivors - if malignancy is diagnosed during treatment remove appliances and use retainers - after treatment orthodontic treatment can be restarted if they have survived 2yrs with no relapse of disease	Zimmermann et al., 2015
Respiratory Disorders		
Asthma	- chronic inflammatory disease causing bronchospasm - episodes vary from mild to severe - if poorly controlled, treat early in the day and minimise stress to ↓ risk of attack - tentative link between orthodontically induced external root resorption and asthma - chronic use of corticosteroid inhalers can result in oropharyngeal candidal infections, especially if wearing removable appliances - advise to rinse and gargle with water after the use of steroids inhaler - may be allergic to aspirin-like compounds, e.g. non-steroidal anti-inflammatory drugs (NSAIDs)	McNab et al., 1999 Dursun et al., 2008
Cystic Fibrosis	- autosomal recessive disorder affecting exocrine glands of lungs, liver, pancreas and intestine - pts have ↓ life expectancy - oral effects include hypoplastic enamel, ↓ salivary flow and delayed eruption	
Neurological disorders		
Epilepsy	- antiepileptic drugs may cause gingival hyperplasia - sodium valproate and phenytoin 50% of pts taking phenytoin have gingival hyperplasia but this resolves spontaneously within 1-6mths of withdrawal of drug - alternatives such as carbamazepine may have oral side effects including oral ulceration and xerostomia - good oral hygiene must be established prior to orthodontic treatment - gingivectomy may be needed post orthodontic treatment - removable appliance not a good idea in pt with uncontrolled epilepsy; FAs are a better option - avoid use of extra-oral appliances	Alawsi et al., 2020
Multiple sclerosis	- complex neurological condition that occurs as a result of myelin sheath damage within central nervous system - most common cause of severe disability among young adults in the UK; incidence of 0.1% (1:1000) in general population, M:F 2:3 - need multidisciplinary approach and may not tolerate long appointments or use of intermaxillary traction - treatment should be tailored to pt, compromised outcome maybe acceptable	Patel et al., 2009 Alawsi et al., 2020
Transplant pts and immune-suppression	- renal transplants not uncommon - drug regimens for transplant pts on an indefinite basis include cyclosporine and nifedipine, both can induce severe gingival hyperplasia - orthodontic treatment should not be refused but practical management is essential, e.g. treat prior to transplant if possible but defer if transplant imminent - pts involved in many hospital treatments and visits, orthodontics should therefore be sensible and simple	

Allergies (see section on Risk Benefit)	• need to know how to treat anaphylactic shock • avoid causing the reaction by using alternative material	Resus Guidelines, 2015
Natural Rubber Latex Allergy (NRLA)	• the number of people with NRLA has ↑ significantly in recent years • dental and medical devices contain NRL • severe systematic reactions have been reported following cutaneous/respiratory exposure • reaction can range from flare/wheel to anaphylactic shock • pts at high risk of developing latex allergy: - spina bifida (24-60%) - urogenital problems - healthcare professionals (5-15%) - atopic pts - latex industry workers - pts undergoing multiple surgical procedures • orthodontic management of pts with NRLA: - need local policy for management - need up to date medical history - if latex allergy suspected refer to dermatologist - use latex free products - latex free elastics subject to ↑ force degradation - treat as first pt of day to minimise airborne particle risk - keep emergency NRL-free drugs and equipment available Types of reaction to NRL • Irritant contact dermatitis (non-allergic reaction) - most frequent cause of hand eczema - due to chemicals used in the processing of NRL and mechanical irritation - eczema leads to broken skin which can have more exposure to allergen • Allergic contact dermatitis - type IV hypersensitivity reaction - due to chemicals used in glove manufacturing process - eczematous rash that is typically pruritic and skin may be swollen, vesicular or weeping • NRL allergy - type I hypersensitivity reaction - occurs 5-60 minutes after contact with NRL - severe systematic reactions have been reported following cutaneous/respiratory exposure - can range from a flare and wheal to full blown anaphylactic shock - may induce delayed hypersensitivity reaction (Type IV reaction)	Field et al., 1998; BOS, 2014 López et al., 2011 Hain et al., 2007 Field & Fay, 1995
Latex diet syndrome	• occurs in 50-70% of pts with latex allergy • due to cross reacting proteins between food (avocado, kiwi, almond, banana) and naturally occurring latex	
Nickel Allergy	• nickel present in majority of orthodontic alloys • 4-29% of population hypersensitive to nickel • no evidence of archwires inducing allergic reaction • ↑ concentration of nickel required intra-orally than on the skin to induce immune response • HG may cause allergic contact dermatitis extra-orally (nickel alloy used in studs) • management of orthodontic pts with nickel allergy: - cover outer bow and studs of HG • if in doubt fit a trial appliance	Jansen et al., 1998 Bass et al., 1993 Dunlap et al., 1989 Burden & Eedy, 1991 Rahilly & Price, 2003; BOS, 2012

Bis-GMA Allergy	- allergic contact dermatitis to dental materials uncommon for pts but may become an issue for dental teams - avoid placing polymer on hands/gloves to ↓ risk - dental materials in their pre-polymerised state are potential sensitisers - cross sensitivity between Bis-GMA and epoxy resin may exist - Bis-GMA monomer in composite bonding agents 1 case report of a 14yr old boy exhibiting hypersensitivity to an orthodontic bonding agent exists	Carmichael et al., 1997 Hutchinson, 1994
Musculo-skeletal disorders		
Juvenile idiopathic arthritis	- drug regimens include: - steroids which may affect growth - NSAIDs which theoretically may inhibit tooth movement - more aggressive treatment includes the use of methotrexate - pts with severe disease have characteristic facial morphology - typical features - CI II/1 incisors on Sk CI 2 base, retrognathic and micrognathic mand, ↑ MMPA, AOB - destruction of condyles is common (45% of cases) - with no condyle, functional appliances have limited effect - no clear guidelines on treatment - surgery may be contemplated at the end of facial growth, including orthognathic, genioplasty and alloplastic TMJ reconstruction	Twilt et al., 2004 Pearson & Ronning, 1996 Abela et al., 2017
Bisphosphonate (BP) treatment	- used for treatment of bone metabolism disorders, e.g osteoporosis, osteogenesis imperfect, bone pain secondary to cancer - have a high affinity for calcium - direct inhibition of osteoclast function, potentially slow tooth movement - antiangiogenic properties - drugs have long ½ life - problems with BP use include impaired bone healing and bisphosphonate induced osteonecrosis - cases have been reported of bisphosphonate induced osteonecrosis during orthodontic treatment - signs and symptoms of osteonecrosis include pain, swelling, pus formation, paraesthesia, ulceration of soft tissue, intra-oral or extra-oral sinus tracts, loose teeth and exposed bone - try to treat prior to starting BP although less risk with oral BP than IV BP	Zahrowski, 2007 Rinchuse et al., 2007
Side-effects of medication		
Drug-induced gingival overgrowth	- compounded by poor oral hygiene - can consider alternative but if the drug is essential need to minimise appliance components and avoid bonded retainers - main drugs are phenytoin, cyclosporine and calcium channel blockers including nifedipine, diltiazem and amlodipine	
Bisphosphonates	see above	
Reduced orthodontic tooth movement	prostaglandins are important mediators in tooth movement, has been suggested that use of over-the-counter NSAIDs can affect efficiency of tooth movement	Arias et al., 2006

	- the effect of aspirin, acetaminophen (paracetamol) and ibuprofen on orthodontic tooth movement in rats → acetaminophen did not affect movement with a significant difference between control, aspirin and ibuprofen groups; suggested paracetamol may be analgesic of choice for orthodontic pts - glucocorticoid therapy has been known to affect bone turnover - ↓ in rats on acute treatment and ↑ in rats on chronic treatment - consider deferring treatment for pts on acute corticosteroid treatment and ↓ orthodontic forces for those on chronic corticosteroid treatment	Kalia et al., 2004 Kalia et al., 2004 Kalia et al., 2004
Endocrine conditions		
Diabetes Mellitus (DM)	- characterised by chronic hyperglycaemia 2 main types: type 1 (Insulin Dependent DM), type 2 (Non-Insulin Dependent DM) - need to know how to treat diabetic emergencies - oral complications include: - xerostomia - burning mouth and/or tongue - candidal infection - altered taste - progressive periodontal disease - dental caries - acetone breath - oral neuropathies - parotid enlargement - sialosis - delayed wound healing - avoid orthodontic treatment in pts with poorly controlled disease → may suffer from periodontal breakdown - need rigorous preventative regimes to minimise risk of periodontal breakdown - may need to plan treatment in similar manner to a periodontally compromised pt - pts prefer appointments which do not interfere with their meal times	
Cerebral palsy and learning difficulties	- consent must be carefully considered, independent mental capacity advocate may be used - ensure parent is supportive of treatment and ideally pt is motivated for treatment - possible problems: oral hygiene, drooling and manual dexterity - clinician approach to behaviour management must be flexible and longer appointments may be required - keep treatment simple, the use of FAs is not precluded - sedation can be used to ease treatment - reasonable adjustment in working practice should be considered - assess each pt individually	Becker & Shapira, 1996 Chaushu et al., 2002; Rada et al., 2015 Ellis et al., 2016 Casaus & Panesar, 2014
Psychiatric Disease		
Body Dysmorphic Disorder	- an irrational and illogical unhappiness related to their physical appearance - main symptom - preoccupation with one or more perceived defects - pts often preoccupied by a range of repetitive behaviours, e.g. mirror checking, excessive grooming, constant reassurance seeking, 'skin picking'	Cunningham & Feinmann, 1998 Rosten et al., 2018

	• important to be aware of the condition but many different manifestations • need psychological assessment and care for the condition prior to any treatment since surgery and possibly even orthodontics is unlikely to be beneficial	
Eating Disorders	• complex aetiology • most common are anorexia nervosa and bulimia nervosa • most have onset during adolescence • oral manifestations of eating disorders include dental caries, erosion, dentinal hypersensitivity, salivary gland hypertrophy, raised occlusal restorations and xerostomia • management must be sensitive and aim is to maintain trust and seek pt consent for a referral to a GMP • dietary advice may be difficult but brushing after vomiting should be avoided and the use of gum or fluoride mouthwash to minimise erosion may be helpful	Waylen, 2021 Ashcroft et al., 2007 Waylen, 2021
Recommended reading	Patel et al., 2009; BOS, 2016a; Alawsi et al., 2020	

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Role of the Dental Care Professional (DCP)

Definition	- a dental care professional (DCP) is any of several professionals supporting a dentist - there are different roles which are there to support the dentist in the safety of pts and to provide treatment to a high standard - all members of the dental team contribute to pt's experience of dental treatment - the quality of teamwork is closely linked to the quality of care the team provides	GDC, 2021
Regulations	- all DCP's must be registered with the GDC and indemnified to legally work within the field of dentistry - dental receptionists do not have to register with the GDC - all DCP's must adhere to the GDC's 9 standards - all DCP's must be trained to deal with any medical emergency within their role, e.g. although a dental nurse or orthodontic therapist are trained, they are not permitted to prescribe drugs as it is outside their scope of practice (exception is the administration of oxygen if required) - dental professionals also work outside the NHS, so the GDC has a responsibility to set learning outcomes which prepare all potential registrants for safe and independent practice from the first day of registration - independent practice does not mean working alone and in isolation, but within the context of the wider healthcare team	GDC, 2013a GDC, 2013a
Dental Nurse	- dental nurses are registered dental professionals who provide clinical and other support to registrants and pts - role includes: -prepare and maintain the clinical environment, including the equipment -carry out infection prevention and control procedures to prevent physical, chemical and microbiological contamination in the surgery or laboratory -record dental charting and oral tissue assessment carried out by other registrants -prepare, mix and handle dental bio-materials -provide chairside support to the operator during treatment -keep full, accurate and contemporaneous pt records -prepare equipment, materials and patients for dental radiography -process dental R/Gs -monitor, support and reassure pts -give appropriate pt advice -support the pt and their colleagues if there is a medical emergency -make appropriate referrals to other health professionals	
Orthodontic Therapists	- orthodontic therapists are registered dental professionals who carry out certain parts of orthodontic treatment under prescription from a dentist - role includes: -clean and prepare tooth surfaces ready for orthodontic treatment -identify, select, use and maintain appropriate instruments -insert passive removable orthodontic appliances; removable appliances activated or adjusted by a dentist -remove FAs, orthodontic adhesives and cement	Hodge et al., 2015

	-identify, select, prepare and place auxiliaries -take impressions; pour, cast and trim SMs -make a pt's orthodontic appliance safe in the absence of a dentist -fit orthodontic HG and facebows which have been adjusted by a dentist -take occlusal records including orthognathic facebow readings -take intra- and extra-oral photographs -place brackets and bands -prepare, insert, adjust and remove archwires previously prescribed or, where necessary, activated by a dentist -give advice on appliance care and oral health instruction -fit tooth separators and bonded retainers -carry out Index of Orthodontic Treatment Need (IOTN) screening either under the direction of a dentist or direct to pts -make appropriate referrals to other healthcare professionals -keep full, accurate and contemporaneous pt records	
Dental Hygienist	• dental hygienists are registered dental professionals who help pts maintain their oral health by preventing and treating periodontal disease and promoting good oral health practice • they carry out treatment direct to pts or under prescription from a dentist • role includes: -provide dental hygiene care to a wide range of pts -obtain a detailed dental history from pts and evaluate their medical history -carry out a clinical examination within their competence -complete periodontal examination and charting and use indices to screen and monitor periodontal disease -diagnose and treatment plan within their competence -prescribe R/Gs -take, process and interpret various film views used in general dental practice -plan the delivery of care for pts -give appropriate patient advice -provide preventive oral care to pts and liaise with dentists over the treatment of caries, periodontal disease and tooth wear -undertake supragingival and subgingival scaling and root surface debridement -using manual and powered instruments -use appropriate anti-microbial therapy to manage plaque related diseases -adjust restored surfaces in relation to periodontal treatment -apply topical treatments and fissure sealants -give pts advice on how to stop smoking -take intra- and extra-oral photographs -give infiltration and inferior dental block analgesia -place temporary dressings and re-cement crowns with temporary cement -place rubber dam -take impressions -care of implants and treatment of peri-implant tissues -identify anatomical features, recognise abnormalities and interpret common pathology -carry out oral cancer screening	

	-if necessary, refer pts to other healthcare professionals -keep full, accurate and contemporaneous pt records -if working on prescription, vary the detail but not the direction of the prescription according to pt needs	
Dental Therapist	• dental therapists are registered dental professionals who carry out certain items of dental treatment direct to pts or under prescription from a dentist • role includes: -obtain a detailed dental history from pts and evaluate their medical history -carry out a clinical examination within their competence -complete periodontal examination and charting and use indices to screen and monitor periodontal disease -diagnose and treatment plan within their competence -prescribe R/Gs -take, process and interpret various film views used in general dental practice -plan the delivery of care for pts -give appropriate pt advice -provide preventive oral care to pts and liaise with dentists over the treatment of caries, periodontal disease and tooth wear -undertake supragingival and subgingival scaling and root surface debridement using manual and powered instruments -use appropriate anti-microbial therapy to manage plaque related diseases -adjust restored surfaces in relation to periodontal treatment -apply topical treatments and fissure sealants -give pts advice on how to stop smoking -take intra- and extra-oral photographs -give infiltration and inferior dental block analgesia -place temporary dressings and re-cement crowns with temporary cement -place rubber dam -take impressions -care of implants and treatment of peri-implant tissues -carry out direct restorations on primary and secondary teeth -carry out pulpotomies on primary teeth -Xtn primary teeth -place pre-formed crowns on primary teeth -identify anatomical features, recognise abnormalities and interpret common pathology -carry out oral cancer screening -if necessary, refer pts to other healthcare professionals -keep full, accurate and contemporaneous pt records -if working on prescription, vary detail but not direction of the prescription according to pt needs, e.g. the number of surfaces to be restored or the material to be used	
Dental Technicians	• dental technicians are registered dental professionals who make dental devices to a prescription from a dentist or clinical dental technician • they also repair dentures direct to members of the public • role includes: -review cases coming into the laboratory to decide how they should be progressed -work with the dentist or clinical dental technician on treatment planning and outline design -give appropriate pt advice	

	-design, plan and make a range of custom-made dental devices according to a prescription -modify dental devices including dentures, orthodontic appliances, crowns and bridges according to a prescription -carry out shade taking -carry out infection prevention and control procedures to prevent physical, chemical and microbiological contamination in the laboratory -keep full and accurate laboratory records -verify and take responsibility for the quality and safety of devices leaving a laboratory -make appropriate referrals to other healthcare professionals -dental technicians can see pts direct to repair dentures	
Clinical Dental Technicians (CDTs)	• clinical dental technicians are registered dental professionals who provide complete dentures direct to pts and other dental devices on prescription from a dentist • they are also qualified dental technicians • pts with natural teeth or implants must see a dentist before the CDT can begin treatment • CDTs refer pts to a dentist if they need a treatment plan or if the CDT is concerned about the pt's oral health • clinical dental technology builds on dental technology • role includes: -prescribe and provide complete dentures direct to pts -provide and fit other dental devices on prescription from a dentist -take detailed dental history and relevant medical history -perform technical and clinical procedures related to providing removable dental appliances -carry out clinical examinations within their scope of practice -take and process R/Gs and other images related to providing removable dental appliances -distinguish between normal and abnormal consequences of ageing -give appropriate pt advice -recognise abnormal oral mucosa and related underlying structures and refer pts to other healthcare professionals • if necessary -fit removable appliances -provide sports mouth guards -keep full, accurate and contemporaneous pt records -vary the detail but not the direction of a prescription according to pt needs	
Other points	• all DCP's once qualified can undertake additional skills to expand on their scope of practice by attending a recognised course (refer to the GDC's scope of practice to see the extended duties for each role) • some DCP's have two or more roles, e.g. dental nurse and orthodontic therapist or dental nurse and dental hygienist and therapist • once qualified DCP's roles are on the GDC register under their GDC number with the qualification that they have undertaken	GDC, 2013b
Recommended reading	GDP, 2013a,b; GDC, 2015	

References

GDC, 2013a, Standards for the Dental Team, GDC publication, www.standards.gdc-uk.org/

GDC, 2013b, Scope of Practice, GDC Publication, www.gdc-uk.org/information-standards-guidance
GDC, 2015, Preparing for practice, [www.gdc-uk.org/docs/default-source/quality-assurance/preparing-for-practice-\(revised-2015\).pdf](http://www.gdc-uk.org/docs/default-source/quality-assurance/preparing-for-practice-(revised-2015).pdf)
GDC, 2021, www.gdc-uk.org/about-us/what-we-do/the-registers/types-of-registrants
Hodge T et al., 2015, Orthodontic Therapists and their integration into the orthodontic team, Ortho Update, 8;14-17

Legislation	Covered by: - Ionising Radiations Regulations (IRR17) 2017 - designed to protect the general public and workers - Ionising Radiation (Medical Exposure) Regulations (IR(ME)R), 2017 - designed to protect pts																												
Terms	Effective dose - broad indication of risk to health from any exposure to ionising radiation - allows for different types of radiation and relative sensitivity of different parts of body Sievert (Sv) - the standard international unit																												
Risks	- unnecessary radiation from diagnostic R/Gs causes 100-250 UK cancer fatalities 25% of all X-ray examinations are dental	National Radiological Protection Board, 1990																											
Medical problems	direct effects - ↓ and abnormal mitosis; degeneration and death of cells indirect effects - change in tissue due to damage to blood supply (<i>endarteritis</i>) constitutional effects - malaise, nausea, vomiting, ↓ blood pressure, peripheral vascular failure (<i>radiation shock</i>) neoplastic change - e.g. skin, bone sarcomas, leukaemia genetic effects - effect shown in offspring of recipient																												
Dose	Doses from dental R/Gs are low: background radiation in UK is 2.7mSv/yr=0.0075mSv/day <table border="1"> <thead> <tr> <th>Examination</th><th>Effective dose (mSv)</th><th>Days background radiation</th></tr> </thead> <tbody> <tr> <td>Periapical/ Bitewing</td><td>0.0003-0.022</td><td>1 hr-3 days</td></tr> <tr> <td>DPT</td><td>0.0027-0.038</td><td>8 hr-5 days</td></tr> <tr> <td>USO</td><td>0.008</td><td>1 day</td></tr> <tr> <td>Ceph</td><td>0.0022-0.0056</td><td>8-16 hrs</td></tr> <tr> <td>Chest Xray</td><td>0.014-0.038</td><td>2-4 days</td></tr> <tr> <td>Dento-Alveolar CBCT</td><td>0.01-0.67</td><td>2 days-3 mths</td></tr> <tr> <td>Craniofacial CBCT</td><td>0.03-1.1</td><td>4 days-5 mths</td></tr> <tr> <td>CT Mandible & Maxilla</td><td>0.250-1.4</td><td>1-6 mths</td></tr> </tbody> </table>	Examination	Effective dose (mSv)	Days background radiation	Periapical/ Bitewing	0.0003-0.022	1 hr-3 days	DPT	0.0027-0.038	8 hr-5 days	USO	0.008	1 day	Ceph	0.0022-0.0056	8-16 hrs	Chest Xray	0.014-0.038	2-4 days	Dento-Alveolar CBCT	0.01-0.67	2 days-3 mths	Craniofacial CBCT	0.03-1.1	4 days-5 mths	CT Mandible & Maxilla	0.250-1.4	1-6 mths	Isaacson et al., 2015
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Reducing dose	A.L.A.R.P. principle - as low as reasonably practicable - no R/G taken unless clinically justified and benefit to pt - collimation of X-ray beam - filtration of beam - rare earth metal intensifying screens - regulation of voltage (60-70 kV for dental equipment) - fast films used, typically F speed - very short exposure times - incorporate warning signals - quality control undertaken	Public Health England and Faculty of General Dental Practice, 2020																											
Orthodontic imaging (see section on Imaging)	- use of CBCT for dental imaging continues to ↑ - CBCT doses are significantly ↓ than conventional CT but still ↑ than conventional dental R/G techniques - CBCT not indicated for routine treatment planning but if 3D imaging required may be preferred to conventional CT	Roberts et al., 2009; Isaacson et al., 2015 Silva et al., 2008																											

Reporting	- the new grading for X-rays as: -A - Diagnostically Acceptable (target of more than 95%) -N - Diagnostically Unacceptable (not greater than 5%) - if a R/G is rated as N, a record should be made which should include the following: a. the date b. nature of deficiency c. known or suspected cause of this deficiency d. number of repeat R/G / images (if taken)	Public Health England and Faculty of General Dental Practice, 2020
Recommended reading	Isaacson et al., 2015; Public Health England and Faculty of General Dental Practice, 2020	

References

Isaacson K et al., 2015, Orthodontic Radiology: Guidelines, 4th Ed, BOS, London

National Radiological Protection Board, 1990, Patient Dose Reduction in Diagnostic Radiology, London, HMSO

Public Health England (PHE) and Faculty of General Dental Practice (UK) (FGDP[UK]) 2020, Guidance Notes for Dental Practitioners on the Safe Use of X-ray Equipment. 2nd Edition. London, UK: PHE and FGDP(UK), ISBN: 978-1-8381964-0-0

Roberts JA et al., 2009, Effective dose from cone beam CT examinations in dentistry, Br J Radiol, 82;35-40

Silva MA et al., 2008, Cone-beam computed tomography for routine orthodontic treatment planning: a radiation dose evaluation, AJODO, 133;640e1-5

Question & Answer Section

Questions

Facial Asymmetry



Figs 1 & 2

1. What is the aetiology of this pt's facial asymmetry?
2. What investigations would you undertake?
3. What treatment is possible for this pt?

Ceramic Brackets



Fig 3

1. What type of ceramic brackets are present in this photograph?
2. What are the problems with ceramic brackets?
3. How have manufacturers attempted to overcome some of the problems with ceramic brackets?

Unerupted Teeth



Fig 4

1. What are the possible causes of the missing upper right central incisor?
2. What investigations would you carry out?
3. What treatment would you carry out at this stage?

Functional Appliance Therapy



Figs 5 & 6

1. What type of functional appliance is this and how does it achieve correction of an increased overjet?
2. What is the cause of the lateral open bite?
3. How is the resultant lateral open bite managed?

Enamel Disorders



Fig 7

1. What is the likely cause of the enamel appearance?
2. What difficulties may present during orthodontic treatment?
3. How might you alter your bonding technique if placement of brackets proved difficult?

Dental Anomalies



Fig 8

1. What teeth are present in this photograph of the upper arch?
2. What is the incidence of these anomalies?
3. What are the problems with orthodontic treatment?

Incisor Morphology



Figs 9 & 10

1. Comment on the morphology in both of these photographs of two different pts.
2. What are the problems likely to be encountered in treatment?
3. How common are these anomalies?

Craniofacial Anomalies



Fig 11

1. What is this?
2. What methods are available to feed children with this anomaly?
3. What are the possible aetiological factors in cleft lip and palate?

Craniofacial Anomalies



Fig 12

1. What is this appearance typical of?
2. What are the initial management difficulties and how are they handled?
3. What are the likely outcomes for facial growth?

Orthodontics and Periodontology



Figs 13 & 14

1. Describe the periodontal problems which may occur in the clinical situations shown in these two photographs.
2. What is the relationship between occlusal forces and periodontal disease?
3. What treatment is indicated in both these cases?

Enamel Discolouration



Fig 15

1. When do these teeth calcify?
2. What is responsible for the discolouration?
3. What other problems may be associated?

Dental Anomalies

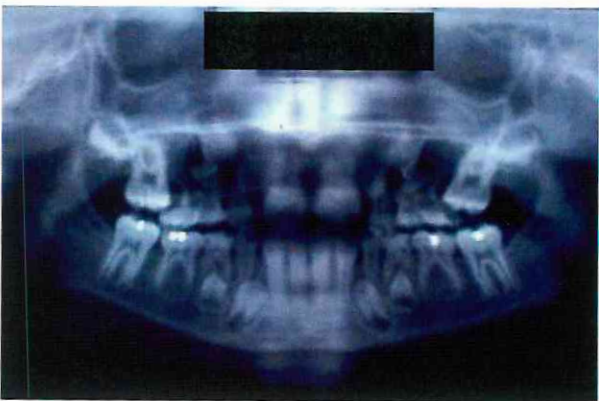
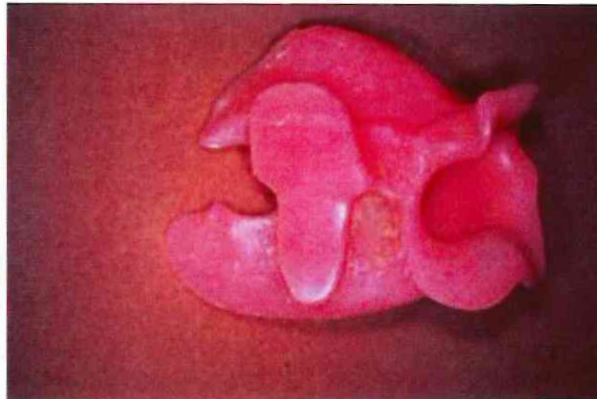
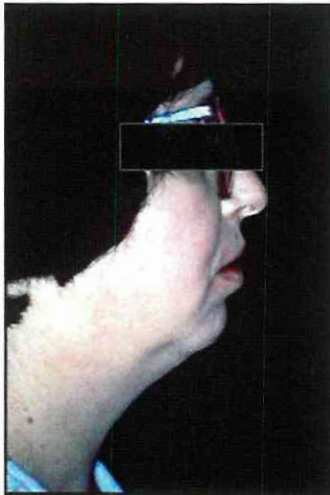


Fig 16

1. What anomalies are present on this radiograph?
2. How common are these anomalies?
3. What are the possibilities for managing these clinical problems?

Adult Orthodontics



Figs 17 & 18

1. This lady complains of tiredness in the morning. What is she likely to be suffering from?
2. What is the cause of this condition?
3. What is the appliance for? How is this condition treated?

Appliances



Fig 19

1. What is this?
2. What are the difficulties associated with using this appliance?
3. How does this appliance achieve its effects?

Appliances

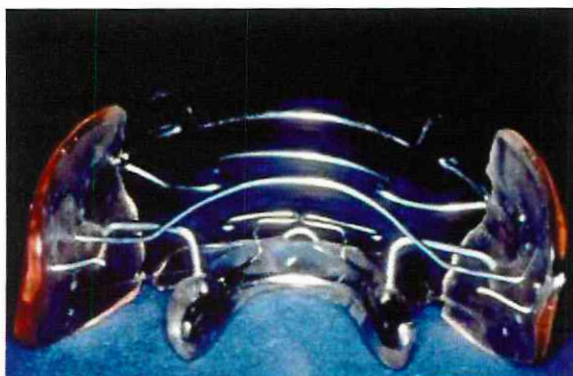
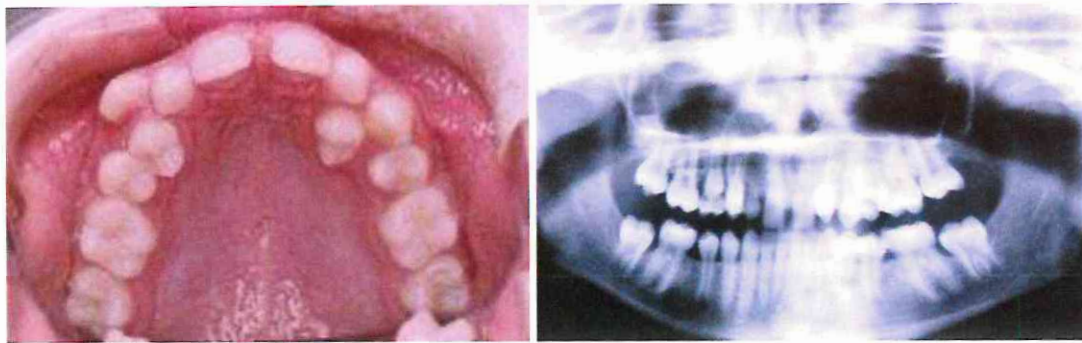


Fig 20

1. What is this?
2. What other versions of this appliance are available and what malocclusions are they used to treat?
3. How do these appliances achieve expansion?

Dental Anomalies



Figs 21 & 22

1. What anomalies are present?
2. What are the possible treatment options for this pt assuming a normal incisor relationship, full class II molars, primary canines of poor prognosis and an uncrowded lower arch with a full permanent dentition?
3. What considerations should be made if substituting the maxillary left lateral incisor with the maxillary left first premolar tooth?

Dental Anomalies



Fig 23

1. What anomalies are present?
2. What investigations would you carry out at this stage?
3. What treatment would be carried out at this stage?

Bonding



Fig 24

1. This canine has been acid etched in preparation for a bond. What is the average depth of etch achieved?
2. How long are teeth etched for?
3. How soon after bonding can a load be placed on a bond?

Appliances



Figs 25 & 26

1. What are these appliances?
2. How do they work?
3. What alternatives exist?

Appliances



Fig 27

1. What is this?
2. What are the difficulties with using this appliance?
3. Describe in detail how this appliance is bonded to the teeth.

Appliances



Fig 28

1. What is this?
2. How is the appliance activated?
3. What is the design fault with the appliance shown here?

Malocclusion



Figs 29 & 30

1. What clinical feature does this adult pt present with?
2. What are the treatment options for this feature?
3. What would be the best treatment option for this pt? Justify your answer.

Appliances



Fig 31

1. What appliance is shown here?
2. What are the disadvantages of this technique?
3. How is treatment likely to progress from here?

Pre-adjusted Edgewise Brackets



Fig 32

1. Why has the upper right lateral bracket been inverted?
2. What are other situations in which this strategy might be adopted?
3. If a canine is brought from the palatal aspect into the line of the arch how is the buccal root torque dealt with?

Orthodontics and Trauma



Figs 33, 34 & 35

1. This 15 year old pt attended at a routine visit reporting that one of his teeth had changed colour (Figs 33 & 34), the 0.016" x 0.022" stainless steel archwire which was removed is shown in Fig 35. What has happened to this tooth and what is the most likely cause?
2. What treatment is indicated at this visit?
3. What is the management of this problem from this point?

Cleft Lip and Palate

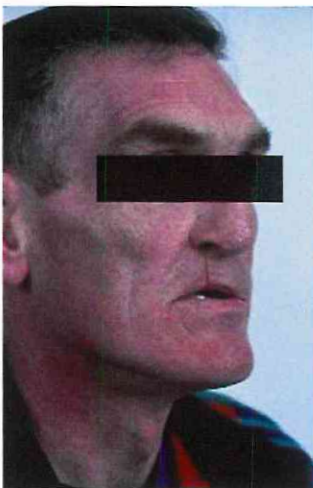


Fig 36

1. What type of lip repair has this pt had?
2. What other types of lip repair do you know?
3. Is the mandibular prominence common in pts with a cleft lip and palate?

Materials



Fig 37

1. What type of wire is being used in this picture and what is the property being exploited for full bracket engagement?
2. The alloy used in this wire is available in 3 different forms with different mechanical properties. What are the 3 forms?
3. What is a potential disadvantage of orthodontic wires made from this alloy?

Iatrogenic Damage



Fig 38

1. What is this?
2. Which teeth are most commonly involved?
3. How might this have been avoided?

Iatrogenic Damage



Fig 39

1. What is this?
2. How can this be minimised?

Friction



Fig 40

1. What does this picture show?
2. What are the advantages of this device?
3. What are the disadvantages?

Mechanics



Fig 41

1. What is being used to derotate this premolar?
2. What other methods could be used?

Appliances



Fig 42

1. Describe the appliance used here to expand the upper arch.
2. What advantages does it give over alternative methods?
3. What design/fitting fault is seen here?

Orthodontics and Periodontology



Fig 43

1. Describe what you see on the left.
2. What are the potential implications?
3. How may these be minimised?

Craniofacial Anomalies



Fig 44

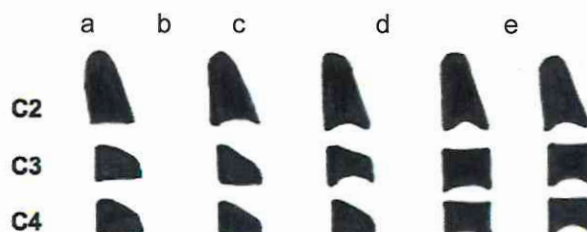
1. This is a front view of this pt, what condition does she have?
2. What general anomalies does it cause?
3. What are the associated dental anomalies?
4. What steps might there be in the management of such a case

Single Best Answer Questions

- 1) A patient with a heart valve defect asks you about antibiotic cover for orthodontic procedures. Which one of the following is the best response?
 - a. There is no routine need for antibiotic cover for orthodontic procedures, but the patient should use a chlorhexidine mouthwash prior to all procedures
 - b. There is no routine need for antibiotic cover for orthodontic procedures, but you should contact the patient's cardiologist or physician for advice
 - c. It is the patient's decision and you should prescribe antibiotics for them if they are keen as well as advise them to use a chlorhexidine mouthwash
 - d. Antibiotic cover is only required for separator placement and band placement as these are the only orthodontic procedures which cause bacteraemia
 - e. There is no need for antibiotic cover for orthodontic procedures and neither is there a need to use a chlorhexidine mouthwash prior to all procedures
- 2) Which one of the following best describes the potential problems associated with a single lower incisor extraction?
 - a. Decreased overjet, decreased overbite, gingival recession
 - b. Increased overjet, increased overbite, space reopening following treatment
 - c. Increased overjet, increased overbite, space reopening, gingival recession, mesially angulated canines
 - d. Increased overbite, increased overjet, space reopening following treatment, gingival recession, loss of interdental papillae
 - e. Decreased overbite, decreased overjet, gingival recession, loss of interdental papillae
- 3) The upper left central incisor of a 9 yr old girl is unerupted even though the upper right central incisor erupted aged 7. The presence of which one of the following is the most likely aetiology for this failure of eruption?
 - a. An unerupted conical supernumerary
 - b. An erupted conical supernumerary
 - c. A single tuberculate supernumerary
 - d. A pair of tuberculate supernumeraries
 - e. A compound odontoma

- 4) Of the following listed transpositions, which one is the most common?
 - a. Mx.C.P1, male, left side
 - b. Mx.C.L2 female, left side
 - c. Mx.C.M1, female, left side
 - d. Mx.C.P1, female, left side
 - e. Mx,C,P1, female, bilateral
- 5) Which one in the following correctly lists the clinical reference points used to divide the face into vertical facial thirds?
 - a. Trichion or Soft tissue Glabella - Subnasale - Soft tissue Menton
 - b. Trichion or Soft tissue Nasion - Subnasale - Soft tissue Menton
 - c. Trichion or Soft tissue Glabella - Subnasale - Soft tissue Pogonion
 - d. Trichion or Soft tissue Nasion - Columella - Soft tissue Pogonion
 - e. Trichion or Soft tissue Nasion - Columella - Soft tissue Menton
- 6) Which one of the following best describes the use of an aluminium wedge when obtaining a cephalometric radiograph?
 - a. It reduces X-ray scatter
 - b. It increases the definition of the overall radiograph
 - c. It helps minimise magnification errors
 - d. It increases the soft tissue definition
 - e. It provides an anterior millimetre measure
- 7) When taking a cephalometric radiograph it is important to get the mid-sagittal plane of the patient's head parallel with the film. Which one of the following is the most likely consequence of failing to ensure this correct patient positioning within the cephalostat?
 - a. The focal distance of the X-ray beam will be reduced resulting in an overall magnification error and enlarged image
 - b. The focal distance of the X-ray beam will be reduced resulting in an overall magnification error and a foreshortened image
 - c. The focal distance will remain the same and the image will remain unaffected everywhere except in the midsagittal plane
 - d. Angular measurements will be adversely affected
 - e. Angular measurements will be unaffected
- 8) Which one of the following statements is true with respect to orthodontic imaging using CBCT?
 - a. CBCT has a higher sensitivity in assessing presence of root resorption (38%) compared with conventional R/Gs (12%)
 - b. CBCT has a higher sensitivity in assessing presence of root resorption (48%) compared with conventional R/Gs (12%)
 - c. CBCT has a higher sensitivity in assessing presence of root resorption (48%) compared with conventional R/Gs (38%)
 - d. CBCT has a higher sensitivity in assessing presence of root resorption (66.7%) compared with conventional R/Gs (12%)
 - e. CBCT has a higher sensitivity in assessing presence of root resorption (55.2%) compared with conventional R/Gs (38%)
- 9) Which one of the following statements best describes the assessments required as part of The Royal London Space Analysis?
 - a. Crowding, levelling the Curves of Spee, arch width, incisor AP position, angulation of teeth, inclination of teeth
 - b. Crowding/ spacing, levelling of the curves of Spee, arch width, incisor AP position, angulation of teeth, inclination of teeth
 - c. Crowding/ spacing, levelling curves of Spee, arch width, impactions, incisor AP position, angulation of teeth
 - d. Crowding/ spacing, levelling curves of Spee, arch width, impactions, rotations, angulation of teeth
 - e. Crowding/ spacing, levelling curves of Spee, arch width, rotations, angulations of teeth, inclinations of teeth

- 10) When assessing space requirements, which one of the following statements is most likely to be correct with respect to space in the absence of space creation using extractions?
- Flattening of a 6mm curve of Spee requires 2mm of space
 - Flattening of a 6mm curve of Spee requires 4mm of space
 - Flattening of a 9mm curve of Spee requires 2mm of space
 - Flattening of a 9mm curve of Spee requires 4mm of space
 - Flattening any increased curve of Spee requires 2mm of space
- 11) Peer assessment rating has different weighting for each component. What is the weighting?
- Crowding = 1; buccal segments = 1; OJ = 6; OB = 2; C/L = 4
 - Crowding = 1; buccal segments = 2; OJ = 6; OB = 2; C/L = 4
 - Crowding = 1; buccal segments = 1; OJ = 6; OB = 4; C/L = 2
 - Crowding = 1; buccal segments = 2; OJ = 6; OB = 4; C/L = 1
 - Crowding = 1; buccal segments = 1; OJ = 8; OB = 2; C/L = 4
- 12) You are on a new patient assessment clinic and a fit and well, 8 year old male patient is referred to you by his GDP. The patient presents with a Class II division 1 incisor relationship and a 9 mm overjet. There is no history of dental trauma. The patient's father wants you to provide treatment now in order to avoid his son having a functional brace when he attends secondary school. Choose one of the following which best describes what you should tell the father?
- There is no evidence that early treatment now is more effective than providing one course of treatment as an adolescent
 - There is low to moderate quality evidence that providing early treatment is more effective than providing one course of treatment as an adolescent. The trauma risk would be reduced by 10%. However, treatment will be longer, and the final occlusion may be compromised
 - There is low to moderate quality evidence that providing early is more effective than providing one course of treatment as an adolescent. The trauma risk would be reduced by 10%. Providing treatment now will mean the overall treatment time is shorter
 - There is good quality evidence that providing early is more effective than providing one course of treatment as an adolescent. The trauma risk would be reduced by 30%. However, treatment will be longer, and the final occlusion may be compromised
 - There is good quality evidence that providing early treatment is more effective than providing one course of treatment as an adolescent. The trauma risk would be reduced by 30%. Providing treatment now will mean the overall treatment time is shorter
- 13) You have just undertaken a retainer review on a 13 year old patient that had received treatment with upper and lower fixed appliances. You have decided to discharge the patient. The nurse wants to know, how long the dental records should be retained. Which one of the following describes what you should tell her?
- They should be retained for
- Until 7 years post treatment
 - Until 11 years post treatment
 - Until the patient is 18 years old
 - Until the patient is 25 years old
 - Until the patient is 26 years old
- 14) Which one of these images of the cervical vertebrae (a to e) would most likely suggest that a patient is at the most suitable stage of growth to utilise a functional appliance?



- 15) In transitioning from the mixed to the permanent dentition, which one of the following is the most influential factor in leading to the establishment of Class I molar relationship?
- Differential growth of the mandible over the maxilla
 - Mesial movement of molars utilising the primate spaces
 - Mesial movement of molars utilising the leeway space
 - An increased in the intercanine widths
 - A change in the inclinations of the incisors
- 16) Which of the following reasons is consistently the most valid for treating a Class II division 1 incisor relationship early, whilst still in the mixed dentition?
- Better cooperation in younger children
 - More favourable changes to the skeletal relationship
 - Improved prognosis for adolescent treatment
 - Improvement in self-concept scores
 - Reduction in trauma to the upper labial segment teeth
- 17) Which bracket prescription and tube alteration would best resist the unwanted consequences of early loss of mandibular first molars during space closure, i.e. retroclination of the lower incisors?
- MBT with the mesial end of the molar tube more occlusal
 - MBT with mesial end of the molar tube more gingival
 - Andrews with mesial end of the molar tube more occlusal
 - Andrews with mesial end of the molar tube more gingival
 - Damon Q with mesial end of molar tube more occlusal
- 
- 18) In a 9-year-old child with mild crowding and who requires extractions, which one of the following is the most reasonable to consider in order to maintain a Class I molar relationship?
- Balancing with the extraction of a primary canine
 - Balancing with the extraction of a mandibular 1st primary molar
 - Compensating with the extraction of a 1st primary molar
 - Compensating with the extraction of a 2nd primary molar
 - Balancing with the extraction of a mandibular 2nd primary molar
- 19) A 10 year old patient is being treated with an URA incorporating posterior bite blocks and an anterior screw to correct an anterior cross bite. They present with the Southend clasp fractured. Which one of the following describes the most likely cause for this clasp fracture?
- The patient has dropped the URA
 - The patient has been using the Southend clasp to remove the URA
 - The wire has been work hardened during manufacture thus resulting in fracture
 - The acrylic baseplate has not been cured sufficiently so the wire has come loose
 - The forward movement of the anterior segment has resulted in the patient biting edge to edge onto the Southend clasp causing it to fracture
- 20) A 15-year-old female patient presents with an edge to edge incisal relationship on a Class 3 skeletal relationship that is suitable for treatment using orthodontic camouflage. They have previously lost an upper left central incisor due to trauma. There has been space lost for the UL1 and the upper centre line is 2mm to the right of the facial midline. Which one of the following best describes the most appropriate management for this case?
- Restore the current space and await completion of growth
 - Treat with orthodontic camouflage, opening space of the UL1 for an implant retained crown
 - Treat with orthodontic camouflage, opening space of the UL1 for autotransplantation of a lower second premolar
 - Treat with orthodontic camouflage, opening space of the UL1 for a resin retained bridge
 - Treat with orthodontic camouflage, moving the UL2 into the space of UL1 and restoratively camouflage this tooth as a central incisor

- 
- 21) About 8-18% of referred patients present with a maxillary transverse deficiency. Which of the following describes a situation where arch expansion is least likely to be required as part of any orthodontic treatment?
- A unilateral crossbite with a displacement on closing into centric occlusion in a 10-year-old patient
 - A unilateral crossbite without a displacement on closing into centric occlusion in a 10-year-old patient
 - Orthodontic treatment in preparation for an alveolar bone graft in a 10-year-old cleft affected patient
 - A bilateral crossbite with palatally inclined upper buccal segment teeth at any age
 - A 17-year-old patient with a Class III incisor and skeletal pattern requiring arch co-ordination prior to orthognathic surgery to enable arch coordination
- 22) Which one of the following statements is incorrect with respect to archform?
- Archform should always be considered in 3 dimensions
 - The Bonwill Hawley archform is a largely historic archform, constructed around an equilateral triangle
 - A prefabricated archform is useful in gaining the closest fit for the majority of patients, therefore individual adjustment is not necessary
 - The pre-treatment archform is the best guide to future stability
 - Archform types are influenced by tooth size, arch width, and inclination of the posterior teeth
- 23) Which one of the following protraction headgear arrangements is most likely to be successful in a compliant patient when treating a Class III incisor relationship?
- 13 year old patient, 400g force per side, 14 hours per day, elastics downwards at 30 degrees
 - 9 year old patient, 150g per side, 8 hours per day, elastics downwards at 30 degrees
 - 13 year old patient, 400g per side, 8 hours per day, elastics upwards at 10 degrees
 - 9 year old patient, 400g per side, 14 hours per day, elastics downwards at 30 degrees
 - 9 year old patient, 150g per side, 14 hours per side, elastics upwards at 10 degrees
- 24) Which of the following post-treatment positions of the lower incisors is considered the most stable?
- Positioning the lower incisor edges on the A-Pogonion line
 - Positioning the lower incisors in a Class I incisor relationship
 - Maintaining the pre-treatment lower incisor position
 - Achieving a lower incisor inclination of 90 degrees to the mandibular plane
 - There are no useful prognostic factors for stability, so final lower incisor position is not important
- 25) Which one of the following is not a way to reduce an overbite?
- URA with anterior bite plane
 - Kim mechanics
 - Incisor intrusion
 - Lower arch reverse curve of Spee
 - Incisor proclination
- 26) The primary dentition transitions into the permanent dentition from approximately the age of six years. Which one of the following is not a feature of the transition phase in the mixed dentition?
- Canines erupt into a wider arch position
 - Incisors erupt into a more labial position
 - 1/2 unit Class II molars
 - Overjet of 6mm
 - Midline diastema
- 27) Which one of the following is the most likely contraindication to starting a (second) fixed appliance phase of treatment following the successful use of a functional appliance?
- Being in the mixed dentition
 - An absence of lateral open bites
 - The presence of large lateral open bites
 - The lower incisors are very proclined
 - Crowding in both the upper and lower arches

- 28) Of the different methods used in predicting pubertal growth as part of functional appliance treatment, which one of the following is the most accurate in determining when the maximal rate of growth has occurred?
- Standing height plotted on a UK-WHO growth chart
 - Hand wrist radiographs
 - Cervical vertebral maturation assessment
 - Peak height velocity plot
 - Serial cephalometric radiographs
- 29) If considering 'limited treatment orthodontics' which one of the following statements is true?
- Patients should only have the limited orthodontic treatment plan discussed with them
 - Practitioners should not work within their competencies
 - Patients should have all treatment options discussed including 'no treatment'
 - This type of treatment can only be undertaken privately
 - Any compromises should not be discussed with the patient prior to starting treatment
- 30) If the UR1 of a 13 year old patient undergoing upper and lower fixed appliance treatment becomes non-vital during treatment, which one of the following should be undertaken?
- All treatment should be stopped and the patient should be debonded
 - All active treatment should be temporarily stopped, and the patient assessed by the GDP
 - Treatment should be continued and treatment of UR1 delayed until debond
 - Treatment should be continued and the patient assessed by the GDP
 - The patient should be debonded, retainers fitted and then assessed by the GDP

Facial asymmetry Fig 1 & 2

1. This pt's facial asymmetry arises from mandibular asymmetry, maxillary asymmetry and cranial asymmetry. The chin point is to the left suggesting a right sided mandibular hyperplasia and a left sided mandibular hypoplasia. The spatula indicates the maxilla has failed to fully develop hence the cant on the spatula. The left orbit is poorly developed compared to the right suggesting an overall craniofacial asymmetry.
2. Study models to examine effects on the occlusion. Pan-oral radiograph to examine condylar and mandibular body development (sometimes consider CBCT of the TMJ). There is likely to be condylar hyperplasia on the right and a relative hypoplasia on the left. The body of the ramus and mandible on the right is likely to be larger than the ramus and body of the mandible on the left. A technetium scan may help identify "hot spots" and thus whether there is excessive bony remodelling in certain areas. An overall assessment of development (secondary sexual characteristics, menarche, peak height velocity) should be made. Facial development continues after puberty but the facial asymmetry is unlikely, in most cases, to significantly worsen once the pubertal growth spurt has finished.
3. During the pubertal growth spurt it is important that the occlusal cant does not worsen. A bite plane to prevent molar eruption (maxillary and mandibular) on the right may help limit changes in the occlusal cant. Once growth has more or less ceased correction is only likely to be possible with surgery to the mandible, maxilla and possibly the remainder of the craniofacial complex.

Ceramic Brackets Fig 3

1. This is a mixture of polycrystalline and monocrystalline brackets. Polycrystalline brackets are opaque whereas monocrystalline brackets are clear.
2. Wires are difficult to disguise and elastomeric modules tend to discolour between visits depending on dietary intake. The property of fracture toughness is a problem. The brackets may fracture and if portions are inhaled these are difficult to detect on radiographs. The use of wire ligatures increases the likelihood of tie-wing fracture. There is little flexibility in the bracket and therefore the problem can be adding additional torque without risking bracket failure due to brittle nature of bracket. The hardness of the ceramic is higher than enamel and therefore the use of these brackets on lower incisors in deep bite cases may cause considerable wear of the upper incisors. Debonding of the brackets causes problems because the bracket composite interface is much stronger than the tooth composite interface. A number of case reports have shown that the enamel may break off with the ceramic composite complex on debonding. De-bonding should therefore be undertaken with caution. All excess composite should be removed from around the face. Manufacturer's instructions and tools for debonding should be used where appropriate. Peppermint oil, electrothermal debonding or the use of high speed diamond burs to grind down the brackets have also been suggested. The friction between stainless steel wires and ceramic is very high, this may result in difficulties with closure of residual extraction space and the use of looped archwires may be indicated.
3. Tooth wear problems may be minimised by using specially adapted modules with an occlusal rubber buffer over the ceramic bracket. Friction may be minimised with metal inserts, the use of ion implanted wire, Teflon covered wires or the development of the zirconium brackets. None are entirely satisfactory, the Teflon coating comes off and zirconium brackets have poor aesthetics. Problems with debonding may be overcome with further development of flexible bases and by the inclusion of a pre-stressed notch in the bracket, e.g. Clarity bracket.

Unerupted Teeth Fig 4

1. Would need to consider traumatic loss of tooth, trauma in the primary dentition and subsequent dilaceration of the permanent incisor, presence of supernumerary teeth, soft tissue impaction, pathology and agenesis (extremely unlikely).

2. A clinical history and clinical examination should be carried out before R/Gs are taken. Radiographic examination, panoramic plus anterior occlusal radiographs. The anterior occlusal radiograph is needed because if the upper right central incisor were palatally positioned the tooth would not appear in the cut of the tomogram. Can use parallax to identify position of the tooth.
3. If there is a supernumerary present this should be removed and consider the loss of both upper primary canines to create space. Remember to consider the age of the pt and the development of the permanent roots of the incisors. A URA can be constructed to move the upper right lateral incisor and the upper left central incisor distally to create space for the eruption of the upper right central incisor or a sectional fixed appliance. This tooth is likely to erupt if a conical supernumerary was present. It is less likely to erupt with a tubercular supernumerary and may need to have attachment and a traction wire or gold chain bonded to the tooth when the supernumerary is removed. A soft tissue impaction would require a minimal exposure together with loss of the primary canines and a removable appliance to move the upper right lateral and upper left central distally. If the upper right central is dilacerated then the prognosis is poor and depends on the extent of the dilaceration. Consider getting a Restorative opinion. (Yaquob et al., 2016)

Functional Appliance Therapy Figs 5 & 6

1. This is a twin block. Overjet correction is achieved by the appliance being worn 24 hours a day, the bite blocks force the mandible to be postured forward. In addition a face bow may be fitted in conjunction with HG to retract the upper teeth and possibly retard maxillary growth. An elastic may be added from the lingual of the lower appliance to the face bow to assist in mandibular protraction and maxillary retraction, originally described by **Clark, 1988** but rarely used now.
2. The lateral open bite arises because of the bite blocks which prevent the maxillary and mandibular buccal teeth erupting. This appliance therefore can be a disadvantage in deep bite cases where maxillary and mandibular molar and premolar eruption should be encouraged. The inclusion of incisor capping should be used in these deep bite cases to prevent over eruption of the incisors and thus worsening of the bite.
3. The bite planes may be trimmed to allow the posterior teeth to erupt. Towards the end of treatment the appliance can be worn at nights only and this allows some molar eruption. A final phase of treatment with a fixed appliance may be required for full interdigitation of the posterior occlusion.

Enamel Disorders Fig 7

1. This could be either fluorotic enamel or amelogenesis imperfecta of the hypoplastic variety (two types: hypomineralized type where the enamel matrix formation is normal but calcification is abnormal; and hypoplastic type where there is defective matrix formation but calcification is normal.) More detailed classification in **Crawford et al., 2007**.
2. If this is amelogenesis imperfecta of the hypoplastic variety there may be difficulties with the etch pattern and retention of the bonds. If the amelogenesis imperfecta was of the hyperplastic variety then ridging and poorly formed enamel may mean that there was less surface enamel to establish an etch pattern. Nevertheless despite reduced enamel it is feasible to bond brackets to these teeth. Bond removal seldom causes problems unless there is severe hypoplasia of the enamel. If the enamel is severely fluorotic (which it was in this case) then there may be difficulties associated with establishing an etch pattern with conventional bonding techniques (**Prado et al., 2020**).
3. With fluorotic enamel there are two approaches:
 - use a conventional bond technique but extend the etching time (2 minutes) and use a thin mix of composite to try and improve the flow of composite tags into the etch pattern. If this fails then the use of glass ionomer cements should be considered.
 - Glass ionomer cement. This cement system does not rely on etch patterns being established in enamel since the adhesion of the cement to enamel relies on chelation with calcium ions rather than a mechanical tagging. The bond strength produced by this system is less than with composite but with care can be successful.

Dental Anomalies Fig 8

1. The teeth present are: 7643221/1223467 The pt has missing upper second premolars and has supplemental upper lateral incisors.
2. Supplemental laterals are seen in 0.31% of the population. Missing upper second premolars are seen in 1.5% of the population. The condition of hypodontia and hyperdontia can be seen in the same mouth.
3. In this case the missing upper second premolars were counteracted by the presence of the supplemental lateral incisors. Nevertheless, a tooth size discrepancy is likely to result and an occlusion with the fulfilment of all six of Andrews' keys is extremely unlikely.

Incisor Morphology Figs 9 & 10

1. The lower incisors on the right have undergone fusion, it is obvious that the lateral and central incisor must have fused since there is only one incisor formed tooth. There is also a talon cusp on the lingual aspect. The photograph of the upper incisors shows that the upper central incisor is a macrodont. There is also a faint line on the labial surface suggesting this tooth may have undergone gemination as opposed to fusion. Gemination and fusion can be distinguished by simply counting the teeth. If fusion has occurred then there is a reduced tooth number. If there is gemination the incisor number is normal but the geminated teeth are larger although fusion can occur with supernumerary teeth. The photograph of the upper incisors also suggest the upper left central incisor may be microdont.
2. Fused teeth are extremely difficult to separate, pulpal connections mean that if this approach is to be considered the teeth are likely to have to be root filled. In both cases shown the possibility of a tooth size discrepancy between the upper and lower arches needs to be assessed. Talon cusps in the upper arch may cause difficulties with correction of the overbite. Any attempts to reduce talon cusps need to be undertaken cautiously as pulpal extensions into the talons are common. Grinding these talons may therefore lead to pulpal exposure.
3. Incidence figures
talon cusps - 1-8% (more common in Mongoloid cases) (Hegde et al., 2010)
double teeth (Schuurs & van Loveren, 2000)
 - fusion - 0.5%
 - gemination - commonly affects lower A's and B's, upper & lower 1's & 2's, 7s & 8's

Craniofacial Anomalies Fig 11

1. This is a unilateral cleft lip and palate. The baby is also wearing a feeding plate and there is labial "strapping" in order to align the major and minor segments.
2. In the third world these children survive - breast feeding under extreme circumstances is possible although extremely difficult. Lambs teats which require little suction have been used. A cup and spoon may also be used to feed the infant milk. A conventional teat with an enlarged aperture (using a scalpel or hot needle) may also help. Specialised teats such as Orthodontic teat from NAM can be used with a squeezable Softplas bottle or the Rosti Bottle which has a shield for obturating the cleft have been developed. The Haberman Teat is a very large and flexible teat with a non-returnable valve has also been used and is very useful in feeding babies with Pierre Robin Sequence. This latter method also has a variable flow control. Feeding plates have been used, but they need to be changed frequently as the child grows (approximately every 10 days to 2 weeks). They are also an added burden to a mother coping with a newborn child. There is no proven benefit for using feeding plates either in passive or active forms.
3. There is no proven genetic link although there are familial associations. Non familial clefting has been ascribed to a mutation in the TGF α locus. Membrane stabilising drugs such as phenytoin have been indicated. It has been suggested that high levels of circulating maternal corticosteroids may be causative. A large tongue may prevent palatal shelf elevation. Similarly a wide face with limited vertical growth may mean the palatal shelves fail to meet and the lack of vertical facial growth at a critical period prevents the tongue from dropping down and therefore the palatal shelves elevating. Vitamin A and

retinoids are known to induce clefting and creams used for acne which contain Vitamin A derivatives have been implicated in the cause of clefting. There is interest in the possibility of prevention by insuring high levels of folic acid three months prior to conception.

Craniofacial Anomalies Fig 12

1. The Pierre Robin Sequence which comprises a triad of cleft palate, micrognathia, relative macroglossia, with air way obstruction and gastric reflux.
2. The feeding problems are the same as for any cleft palate child but the large tongue and the fact that neonates are obligate mouth breathers means that respiratory distress may occur during feeding. Feeding may therefore be by oral gastric tubes initially, if not possible with a Haberman type feeder. The main problem is respiratory distress. If there is lack of tongue control the large tongue may cause obstruction. Oropharyngeal airways may also need to be used.
3. In most cases mandibular growth will catch up with maxillary growth and the profile will appear relatively normal.

Orthodontics and Periodontology Figs 13 & 14

1. The lingually placed upper incisor has caused the lower incisor to be labially placed. The gingival margin of the lower incisor is already lower than on the adjacent incisors. The lower incisor may therefore be labially positioned in labial bone which could result in fenestration. The lingual fraenum has already had some effect (recession) on the lingual gingivae of the lower incisors. The continual action of the tongue is likely to worsen the situation with age.
2. It is generally agreed that occlusal forces alone are unlikely to cause periodontal breakdown. Where there is uncontrolled periodontal disease then occlusal forces may hasten periodontal breakdown. Much of this work is extrapolated from animal experiments and since effects of periodontal disease vary between individuals this view must be treated with some caution.
3. The upper incisor should be proclined to eliminate the occlusal effects on the lower incisor as well as a probable displacement of the mandible. A removable appliance may be used but an alternative is a lingual bond on the upper incisor and a labial bond on the lower incisor with a cross elastic. This has the added benefit of pulling the lower incisor lingually and therefore away from the labial plate. The extrusive component of the cross elastic is also an advantage in maintaining an overbite on the upper incisor and therefore limiting relapse due to lack of overbite. The lingual fraenal attachment can be surgically removed.

Enamel Discolouration Fig 15

- 1 4-6 mths in utero, these are BA/AB.
- 2 This green appearance is due to high levels of circulating bilirubin. The bilirubin is deposited within the dentine and the primary teeth then take on a green appearance. Superimposed on this green staining is an enamel hypoplasia and hence the chronological appearance of the staining.
- 3 Hyperbilirubinaemia in pre-term newborns is a common occurrence and with improved survival rates this discolouration may be seen more frequently in the future. If levels are excessively high then deposits in the brain stem may lead to irreversible brain damage. This is often referred to as kernicterus or haemolytic jaundice of the newborn.

Dental Anomalies Fig 16

1. All four second premolars and both lower second molars are missing. None of the third molars are developing both upper first molars have impacted under the upper second primary molars.

2. Third molars are the most commonly missing teeth (25-35%), upper second premolars are missing in 1.5% of the population, lower second premolars are missing in 2.6%. Missing lower second molars are seen in 2% of the population. The incidence for impaction of upper first molars into upper second primary molars is 2-6%.
3. The prognosis for both upper second primary molars is poor and these teeth would probably need to be extracted. Any pulpal involvement and infection would necessitate the extraction of these teeth. If the lower arch is uncrowded, consideration might be given to leaving the lower second primary molars in situ and monitoring. At a later date after these teeth have been lost then cosmetic replacement such as a resin retained bridge or single tooth implants can be considered or accepting the space. This would leave the upper molars in a full unit post normal relationship and the upper second molars would then have occlusal contact with the lower first molars. Alternatively, if the lower second primary molars were removed and the case treated to Class 1 then consideration would have to be given to extraction of both upper second molars to prevent their over eruption.
The impacted upper first molars may be dealt with by extraction of the upper second primary molars as already suggested. If this was diagnosed at an earlier stage or was less severe than either separating elastics or brass wire separation could be used to disimpact the upper first permanent molars. It is also possible to use a removable appliance with springs to move the upper first molars distally although engagement of springs in an impacted tooth is difficult. Addition of a composite resin tag to the impacted tooth may facilitate spring engagement.

Adult Orthodontics Figs 17 & 18

1. Obstructive sleep apnoea.
2. This is often seen in middle aged males and females (after the menopause) where fat is deposited in the pharyngeal walls. This reduces the air space which is obstructed by the tongue during sleep. Obesity and alcohol consumption are precipitating factors.
3. The functional type appliance is constructed so that the pt postures forward. The anterior air hole allows the pt to breath normally. By posturing the mandible forward the tongue space is increased and therefore the tongue is less likely to obstruct during sleep. Behavioural management and the use of Continuous Positive Airway Pressure (CPAP) is considered the 'gold standard' treatment for sleep apnoea but another treatment option includes considering a surgical approach (mandibular osteotomy).

Appliances Fig 19

1. A reverse face mask similar to that described by Delaire (Protraction HG).
2. Pt compliance needs to be good. Pts can complain of sweating underneath the chin cups. This can be overcome by customising, perforating the chin cup and forehead pads or placing cotton linings underneath the forehead plate and chin cup. The elastics may cause drooling with inflammation at the angle of the mouth. Direction of pull may also present difficulties.
3. Most of the effects seen are due to tooth movement. There is no good evidence that skeletal "modification" can be achieved on a long term basis (**Mandall et al., 2012, 2016**).

Appliances Fig 20

1. This is a Frankel Appliance - FR1b
2. FR1a - Class I malocclusion, 1b - mild Class II Division 1 malocclusion, 1c - Severe Class II Division 1 malocclusion, FR2 - Class II Division 2 type malocclusion, FR3 - Class III malocclusion, FR4 - Anterior open bites.
3. Frankel believed that the buccal shields modify the soft tissue functioning and that the cheeks are pulled away from the buccal teeth. Furthermore, the traction of the cheeks on the periosteum applies traction to the alveolar bone and allows the upper arch to "develop". There is no active screw appliance in order to achieve this expansion.

Dental Anomalies Figs 21 & 22

1. Developmentally absent left and right maxillary lateral incisors and third molars.
Retained primary maxillary canines.
Transposition of the maxillary left first premolar with the maxillary left canine. (Mx.C.P1).
2. All treatments would involve the extraction of both maxillary primary canines.
Extraction of both maxillary first premolars and alignment for prosthetic replacement of both missing maxillary lateral incisors.
Extraction of the maxillary left first premolar and alignment placing the maxillary right canine in the position of the right lateral incisor and prosthetic replacement of the left lateral incisor.
Attempt to unravel the transposition of the maxillary left first premolar tooth, placing the upper canines in the position of the lateral incisors.
Accepting the transposition, placing the maxillary left first premolar in the position of the left lateral incisor and the right canine in the right lateral incisor position.
3. Consideration of bracket prescription, the tip and torque of the left first premolar bracket may not be required if replacing the lateral incisor.
Effects of the upper premolar palatal cusp interfering with the functional occlusion. The palatal cusp can be gradually reduced over a period of time to reduce possible pulpal damage.
Colour and shape of the upper premolar tooth that could be improved with crown adjustments or composite build-ups.
The two divergent roots of an upper premolar could result in a dehiscence of the labial alveolus.

Dental Anomalies Fig 23

1. Both permanent central upper incisors are large. The pt is in the mixed dentition but the upper right B is missing, an upper primary incisor has been retained and the two centrals have been displaced laterally.
2. Probably limit radiographic investigation to an anterior occlusal radiograph only in view of the pt's age. The anterior occlusal is needed to determine the presence of the laterals and whether the midline tooth is a retained primary tooth, supernumerary or possibly a transposed permanent lateral incisor. This latter option, although rare, is possible. It is also possible that the upper lateral incisors will be missing and the macrodont central incisors although not excessive in this case could represent a fusion between the central and lateral incisors (unlikely in this case).
3. Limit treatment to removal of the retained primary incisor. A period of spontaneous correction of the upper central incisors should be allowed. In light of the pt's stage of dental development it is common to see a median diastema present. If this diastema does not close with the eruption of the permanent laterals and canines then this can be treated in the full permanent dentition.

Bonding Fig 24

1. The average depth of etch is 14-20µm, but can range from 5-50µm.
2. Previously etching with 37% orthophosphoric acid was for 60 seconds. It was later shown that bond strengths did not diminish significantly if this etch was applied for 30 seconds. More recently it has been shown that a satisfactory etch pattern can be established after 15 seconds but that the wash period with the shorter etching time needs to be extended in order to remove the insoluble products.
3. This depends on the bonding system being used. The light activated composites and resin modified glass ionomers can be loaded immediately after curing. Conventional two paste field chemically cured composite resins should be left for four minutes before loading.

Appliances Figs 25 & 26

1. Palatal Arch with a Nance button and lingual arch in use as space maintainers.
0.9 or 1.0mm stainless steel wire is used to form the arches. The wire is soldered to the molar bands, and the Nance button is made from acrylic resin. The thickness of wire used is dependent on the length of the arch and on the anticipated forces of occlusion.
2. The appliances are cemented in place, reducing anterior movement of posterior teeth and posterior movement of anterior teeth. Molars are prevented from rotating mesially and palatally/lingually. The buccal cortical bone plate may help to prevent anterior movement of the molar teeth but there is little evidence to support this. The Nance button contacts the palatal mucosa; the mucosa and underlying bone resisting anterior movement. Poor oral hygiene can cause the Nance button to embed into the mucosa. The lingual arch is contoured so that it contacts the lingual surfaces of the lower incisor teeth.
3. Space maintainers available:

Fixed	Band and Loop design	Maintain space if a single primary tooth is lost prematurely
	Distal Shoe design	Used when second primary molar lost prematurely, and stops mesial eruption of first permanent molar
Removable	Upper Removable Appliance	These are useful if more than one tooth is lost prematurely, can incorporate a prosthetic tooth Rarely used in lower arch
Combination	Headgear attached to molar bands	Worn at night to prevent forward movement of molar teeth into extraction sites

Appliances Fig 27

1. A lingual fixed appliance.
2. The main difficulties are placement of the brackets and a short interbracket span which leaves little flexibility for tooth movements. The amount of wire bending involved with this technique is considerable although customised archwires are available with some techniques, e.g. Incognito.
3. There are many techniques described for indirect bonding. The brackets need to be attached to a model of the pt in the correct position. A suck down splint can then be created over the brackets, the bracket base is cleaned and the teeth prepared for bonding in the usual way. The use of no mix pastes is a method for attaching the brackets to the teeth. Alternatively, a light cured composite can be considered. Direct bonding with this technique is technically difficult although increasingly used for anterior sectionals.

Appliances Fig 28

1. A hyrax screw bonded for rapid maxillary expansion.
2. The pt is asked to turn the screw twice a day (0.25mm per turn). They must be warned of the appearance of a midline diastema. The pt should be reviewed after 7 days and then a further 3 days later. If the suture has not split at this stage then any further activation must proceed with caution otherwise the buccal roots may perforate the maxillary buccal plate of bone. The expansion achieved with a rapid maxillary expansion appliance is no more stable than that achieved with other methods. However, there is less tipping of the molars than with other techniques.
3. A soldered bar should be placed between the first premolars and first molars otherwise the second premolars may be left behind. In this particular case this will help align the marginal ridges of the first and second premolars.

Malocclusion Figs 29 & 30

1. This pt presents with left posterior cross bite. A unilateral posterior crossbite with displacement indicates a symmetrical or bilateral narrowing of the maxilla and is usually only dentoalveolar in nature. Unilateral crossbites without displacements may indicate a more serious skeletal discrepancy and are more difficult to treat because the anchorage demands are higher and the available anchorage is less. The presence of a displacement makes treatment easier because the anchorage demands are not as high as transverse correction is needed in both maxillary quadrants.
2. An upper removable appliance with a midline expansion screw $\pm$ posterior capping.
A quadhelix.
Rapid maxillary expansion with a hyrax screw.
Surgically assisted rapid maxillary expansion.
Osteotomy for transverse expansion.
3. Adults are less likely to adapt to a removable appliances, they have difficulty with speech and eating thus, compliance can be a problem.
The use of rapid maxillary expansion is not possible because the mid palatal suture is fused in adults. If there is no underlying skeletal discrepancy and the malocclusion is not severe, then orthognathic surgery cannot be justified.
Surgically assisted rapid maxillary expansion involves lateral and anterior osteotomies. Indications include: young adults with only a transverse discrepancy and unilateral or asymmetric narrowing of the maxilla.
The next surgical option is more complicated and involves a LeFort I down fracture and 2-4 segmental osteotomies. Expansion occurs in the premolar-molar region.
The use of a quadhelix appliance may be the best option for this pt because the transverse discrepancy is symmetrical and easily corrected with this appliance in 2-3 mths. It is usual to obtain 2mm expansion per mth.

Appliances Fig 31

1. The canines are being retracted with sectional edgewise appliances.
2. The main disadvantages are the lack of control, the canines may tip and flare buccally. The technique can be anchorage demanding and reactivation of sectionals with tie-back loops means that activation is often very short. There may also be rolling of the molars which is difficult to control.
3. Once the canines are retracted the incisors will be bonded. Utility arches will then be used to reduce the overbite and finally the posterior and anterior segments will be fully integrated.

Pre-adjusted Edgewise Brackets Fig 32

1. The root of the tooth is palatally positioned. Normal torque on the lateral incisor bracket is in the palatal direction, by inverting the bracket the torque is reversed and the root will move labially rather than palatally. The tip and 'in/out' is identical, it is only the torque which is reversed.
2. If canines are being moved mesially to take the place of lateral incisors then a degree of palatal root torque rather than buccal root torque is desirable. By inverting the canine bracket the buccal root torque will be changed to palatal root torque. This also has the advantage that the bracket base is designed to fit the curved labial face of the canine rather than using a lateral bracket. If the canine face is very flat then a lateral bracket might be used instead of a canine bracket. In Class III cases, right and left canine brackets can be swapped in order to reverse tip and prevent the canines moving mesially.
3. Obviously inverting the canine brackets is of no use (this will simply increase the amount of palatal root torque because the torque in canine brackets is to move the root buccally). Therefore the only way to increase buccal root torque is to add torque to the archwire. Some have suggested placing a premolar bracket which has more buccal root torque and also a similar curved base to increase the amount of buccal root torque on the canine. The tip would have to be compensated for and this means that the bracket would inevitably have to be changed back to a canine bracket at some stage.

Orthodontics and Trauma Figs 33, 34 & 35

1. The upper right central incisor has become non-vital.
The most likely cause is direct trauma to this tooth. In fact the pt was kicked in the mouth during a rugby game and did not notice any problems until the tooth changed colour.
2. It is important to undertake a full history and document the findings in the pt's records. The current recommendations are that a flexible aligning archwire (e.g. 0.012" NiTi) should be placed initially to reposition the tooth and the pt referred to his GDP for investigation and management of this tooth.
3. Once suitable alignment has been achieved, not necessarily full alignment, then a 'rest period' from active orthodontic treatment should be allowed in order to undertake the necessary root treatment and to allow the supporting tissue to recover. In this case a 3 mth break from tooth movement would be recommended. The appropriate radiographs should be taken initially and careful radiographic monitoring during the remaining treatment is also recommended to check for root resorption. At all stages careful recording of the clinical findings and any treatment undertaken should be made in the pt's records.

Cleft Lip and Palate Fig 36

1. Straight line closure.
2. There are many different types of lip closures available but the common ones are the Tennison and Millard repairs.
3. Mandibles in cleft pts are smaller than the norms for the population. The relative mandibular protrusion is due to a maxillary retrusion. The maxillary retrusion is thought to occur because of scarring of the maxilla as a result of surgical repair of the palate.

Materials Fig 37

1. This is a nickel titanium alloy wire and it is being cooled to gain full bracket engagement. It is therefore classified as thermally activated or heat activated. A freezing solution is being applied to the wire which alters the crystal structure and therefore the mechanical properties. This enables the wire to be distorted fully into the bracket slot and tied in. Once the cooling has been removed and the wire heats up in the mouth, the crystal structure alters back again, the wire becomes stiffer and applies a force to move the tooth.
2. The three types of nickel titanium alloy available are:
 - Martensitic Stable - this displays linear elasticity at clinically encountered temperatures
 - Austenitic Active - otherwise known as pseudoelastic or superelastic NiTi. This displays stress induced phase transformations and therefore non-linear elasticity
 - Martensitic Active - otherwise known as heat activated or thermally active wire. This can undergo both heat induced and stress induced phase transformations at temperatures around mouth temperature.
3. The principal disadvantage of NiTi wires is that they are not easy to bend and therefore to customise arch forms. They are therefore usually purchased preformed.

Iatrogenic Damage Fig 38

1. Decalcification which has occurred during orthodontic treatment.
2. Upper lateral incisors, mandibular canines and premolars.
3. Good oral hygiene instruction, dietary control, use of fluoride toothpaste, daily fluoride rinses and the use of glass ionomer cements on the molar bands. Remember the release of fluoride from glass ionomer cements is very rapid but the cement is then capable of reabsorbing dietary fluoride continuing to act as a reservoir for fluoride long after the initial fluoride has leaked from the cement.

Iatrogenic Damage Fig 39

1. Allergy to a metal 'studs' in cervical pull neck strap.
2. Use of alternative metals with no nickel. Placement of sticky plaster or tape around the metal part of the neck strap.

Friction Fig 40

1. A self ligating bracket.
2. Reduction of frictional resistance to sliding compared with conventional brackets and ligation.
Full engagement of bracket will always be noted if wire can be placed in slots and bracket closed.
3. May not be able to engage very rotated or malaligned teeth, more difficult to partially tie in.
Extra play in bracket is noted producing unwanted tip and torque during space closure, rotations may not full correct.
Full engagement of full-dimension wires may not be possible unless there is good alignment.
Archwire can swivel in tubes.
Can be bulky.

Mechanics Fig 41

1. A lingual cleat is bonded to the palatal surface of the rotated premolar. The buccal face of the tooth is partially obscured, limiting correct placement of the bracket on the facial axis point of the crown. By derotating the tooth against the archwire with powerchain, the bracket can be correctly positioned and full engagement achieved in a light aligning wire.
2. Lingual buttons, Begg brackets & derotation loops are additional lingual accessories, or gradual derotation using aligning wires in the bracket. This is a slower option, complicated by the acute angle between the molar tube and premolar bracket. Initially, the bracket would only be partially engaged and as rotation improved, a steel ligature could be used to maintain the wire in full engagement with the bracket. Positioning of the bracket would need to be changed as the tooth rotated and the facial axis point became visible. Alternatively, the anchorage balance could be altered by tying the upper right 3 to upper left 6 together, and power chain placed from the mesial tie wing of the rotated premolar to the distal tie wing of the right canine. Again, once the facial axis point became visible, bracket positioning on the premolar would need to be changed.

Appliances Fig 42

1. A fixed Quadhelix. Made in 0.9mm stainless steel wire, it is soldered to the lingual surface of the molar tubes. Palatal arms extend to the teeth to be incorporated in the expansion. Activation is usually to half a tooth width on either side.
2. The fact that it is fixed in the mouth means that minimal pt co-operation is required to gain expansion. The movement achieved is largely through tipping of the buccal segments, much as a removable appliance would produce. Differential expansion and derotation of molars can also be achieved with a quadhelix, unlike with a removable appliance. RME produces more bodily movement of the buccal segments rather than tipping, but is indicated in a more select group of pts. However, with the quadhelix, pts can complain of discomfort in the region of the helices and on the dorsal surface of the tongue. In severe cases the quadhelix can become embedded in the palatal tissue, and needs to be surgically removed.
3. The palatal arm in the upper right quadrant is not contacting the upper right 5. Differential expansion will result.

Orthodontics and Periodontology Fig 43

1. Gingival recession on LR1
2. Poor oral hygiene and or proclination of the lower labial segment may lead to a worsening of recession; potential litigation if the pt has not been adequately informed of this risk.
3. Good oral hygiene, care not to procline the lower labial segment and informed consent; the pt needs to be warned about the possibility of the dehiscence worsening as a result of treatment. If the lesion worsens then a free gingival graft or rotated flap is an option to rectify the situation.

Craniofacial Anomalies Fig 44

1. Cleidocranial dysplasia.
2. Autosomal dominant condition of, hypoplasia or aplasia of clavicles, delayed ossification of fontanelles, with a large short skull. Mostly affects membranous bone formation.
3. Dental characteristics are, retention of primary dentition, presence of multiple supernumerary teeth, and noneruption of the permanent dentition. The palate is high and arched and may have some degree of clefting. Many teeth have abnormalities such as dilaceration or gemination. Hypoplasia of secondary cementum may occur. However first permanent molars typically erupt normally. (see **Becker, 1997a,b**).
4. Referral to clinical geneticist if, not already diagnosed and counselled.
Supernumerary teeth, fibrous gingiva and sclerotic bone all contribute to obstructing eruption. Management strategies involve combined surgical and orthodontic planning to remove these barriers surgically at the appropriate time. Timings and number of surgical interventions varies in the different recommended approaches.
Essentially the primary teeth with the bone covering permanent tooth crypts, is surgically removed and packs are placed to allow eruption. Orthodontic objectives are planned individually.

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Single Best Answers

1. b
2. d
3. c
4. d
5. a
6. d
7. d
8. b
9. b
10. c
11. a
12. b
13. d
14. c
15. c
16. e
17. b
18. d
19. b
20. d
21. b
22. c
23. d
24. c
25. b
26. d
27. c
28. d
29. c
30. b

ISBN 978-0-9562712-5-9



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